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13. ABSTRACT A prominent phenomenon of the transonic flight regime is the potential for limit cycle oscillation (LCO) development. LCO is a stable oscillation produced by aeroelastic interactions within a component of the aircraft. Such oscillation shortens the fatigue life of the aircraft and increases the amount of maintenance necessary. These aspects are of great concern to the aerospace industry, particularly with high performance military aircraft that are required to operate beyond their planned service lives. The research here focused specifically on the aircraft wing and the influence of external stores attached to that wing on its aeroelastic properties. Monte Carlo simulations were performed to estimate the probability of a wing undergoing limit cycle oscillations due to external stores. Simulations were conducted with a finite element structural model of a wing coupled with multiple subsonic and transonic unsteady aerodynamics solvers to compare computational cost and accuracy. The results provide guidance for implementing probabilistic analysis methods with industry-standard software to predict dangerous aeroelastic response processes that sometimes occur during flight tests. For the low transitional Mach numbers (between 0.7 and 0.88), the linear aerodynamic model was found to be a viable alternative to the more computationally costly alternatives. For Mach numbers above 0.88, nonlinear, viscous methods were necessary.

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VARIABILITY AND MODEL ADEQUACY IN SIMULATIONS OF STORE-INDUCED LIMIT CYCLE OSCILLATIONS

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Keywords. Aeroelasticity, Limit Cycle Oscillation, Goland Wing

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1 INTRODUCTION

1. 1 Background

Risk management is a key component of engineering. As technology advances systems become increasingly complex, and with this complexity comes increased risk of unanticipated failure modes [1]. A single component's misfire or unanticipated dynamics can cause the entire system's malfunction. For complex military aircraft, system malfunction can mean lost mission objectives, multi-million dollar national investments, or human life. The negative impact of any one of these failures makes the field of risk assessment research an integral component to improving the future success of the United States military.

The flight conditions that fighter aircraft experience are extreme. The demands of high maneuverability at transonic speeds place the aircraft in a league of their own for performance requirements. In entering this demanding flight regime, however, the aircraft has exited the realm of current predictability, as accurate computational flight models for practical design usage have not been fully developed for certain important aspects of transonic flight.

One piece of the complete flight model involves developing an understanding of the aeroelasticity involved in modern day aircraft. Aeroelasticity combines the principles of structural dynamics and aerodynamics to study their interaction and potential instabilities [2].

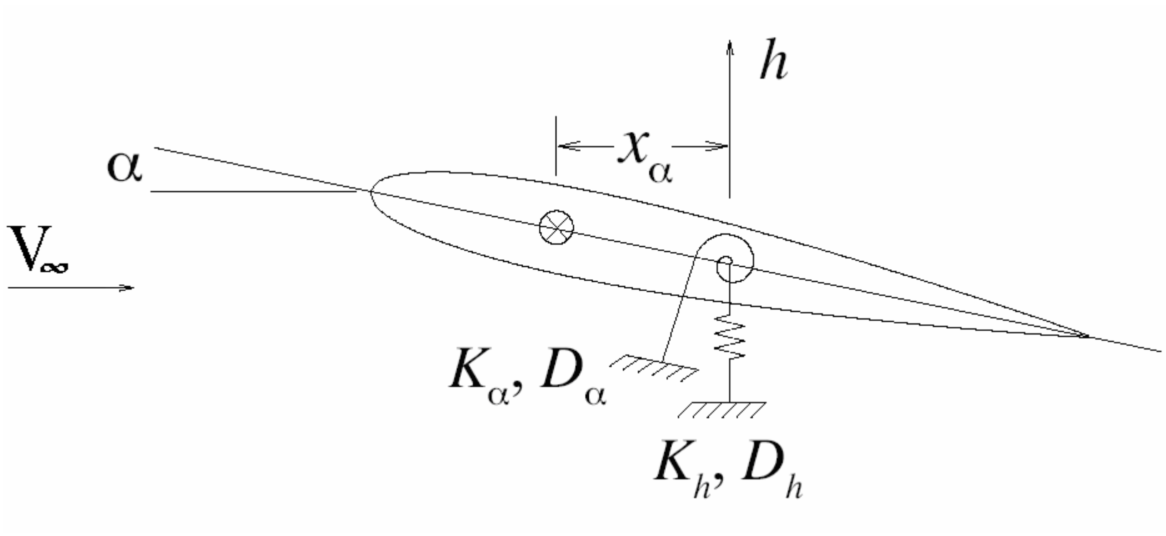


Figure 1. Airfoil with Lumped Structural Properties and Degrees of Freedom [3]

Figure 1 depicts an aeroelastic model of a standard, symmetric airfoil with two degrees of freedom, pitch and plunge. Structural stiffness terms K_h and K_α and damping terms D_h and $D_{\alpha,}$ are incorporated in the pitch and plunge degrees of freedom of the airfoil [4]. Additionally, α represents the angle of attack, *h* represents the vertical displacement, and x_α represents the offset of the elastic axis from the aerodynamic center. The dependence of the aerodynamic forces on the structural response creates the potential for static and dynamic instabilities to occur.

Interaction between aerodynamic loads and structural deformation further complicates the already complex process of analyzing air flow in the viscous, transonic regime. To compute unsteady aeroelastic forces acting on an aircraft, a coupled method is often required to predict the time-dependent response. The researcher must first predict the surface pressure distribution over the aircraft, and then compute the resulting material deformation. The new deformed body surface is used to predict the new surface pressure distribution, and this process is repeated until a converged solution is achieved at the specified time. If the structure is vibrating or the aerodynamic forces vary with time, this procedure must be repeated at each interval.

This process becomes even more complex in the transonic region of flight. This region corresponds to Mach numbers 0.8 through 1.2. In this transitional region, the aircraft itself may not be flying faster than the speed of sound, but some locations in the air flow around the aircraft will have already broken the barrier. Such locations will experience the compressibility effects of shock waves and flow expansion that characterize supersonic flow while those locations that are still subsonic will not. The relatively unpredictable co-existence of subsonic and supersonic flow characteristics creates non-linearity in the flow field and thus complicates the flight model [5]. Viscous interactions of the shocks with the boundary layer even further complicate the flow physics and reduce the predictability.

A prominent aeroelastic behavior in transonic flight is limit cycle oscillation (LCO). LCO is a self-sustained, stable oscillation of limited amplitude produced by aeroelastic interactions [6]. The limited-amplitude nature of these oscillations can arise from aerodynamic and structural nonlinearities. LCO develops when nonlinear structural and aerodynamic forces are in a balance with inertial forces such that the oscillation is bounded and self-sustaining. Under small disturbances, this oscillation remains stable in frequency and amplitude. An example of LCO is illustrated in the front and side views of an F-16 in Figure 2.. During LCO, the wing and the store tip missile will oscillate continuously, bending and twisting back and forth between the limits outlined in red.

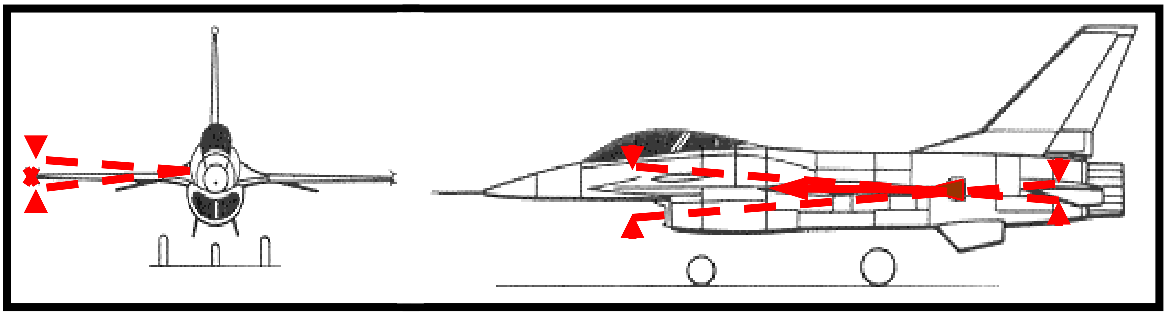


Figure 2. LCO Illustrated with an F-16 Aircraft [7]

While such oscillation is not likely to lead to catastrophic failure, it does put more oscillatory stress on the structure than it was designed to withstand, so a reduced fatigue life for materials must be anticipated. Mission readiness of aircraft is impacted, as maintenance schedules must be stepped up to check for the formation of fatigue cracks and the existence of small but still tolerable cracks may lead to restrictions on payload capacity or configurations. LCO in some cases also impacts the comfort level and performance of the pilot. Finally, the safe release of external stores can be inhibited. At present, no dependable

methods exist for predicting LCO in complex aeroelastic systems before they are observed and analytical models must be calibrated to reproduce the observed behavior.

1.2 Current Research

The prediction of LCO is one of many barriers to the development of all-encompassing computational flight models. In addition to the complexities of military aircraft flight performance, LCO is made more complex with the addition of external stores to the wing because each unique store contributes its own aerodynamic, inertial, and structural influences to the overall aeroelastic characteristics of the platform.

Certain configurations of stores on particular aircraft have proven in practice to be more likely to induce LCO behavior than others. With no reliable predictive models, the military has developed guidelines for possible store configurations based primarily on trial-and-error. For example, the U. S. Military's 15% flutter safety margin in use today was developed from empirical data collected prior to 1960 [3]. LCO avoidance measures are similar in character.

For stores clearance, the repeated flight tests needed to assess the safety margins are significant drains on time and money. Further, the impracticality of testing every possible aircraft with every possible weapons configuration under all possible flight conditions is obvious. As computers have evolved, so has their ability to produce accurate models of structural behaviors. Software technology advancements are beginning to provide viable alternatives to the trial-and-error test methods, but the most time- and cost-effective approach to providing reliable information to decision-makers has not been agreed upon.

Within the research presented here, such alternative methods are considered and compared for two criteria: predictive accuracy and computational cost. Predictive accuracy is the superior requirement. Computational models will never produce the realistic data that flight testing does, but, through research, computational models can produce data that are close enough to the real world for researchers to draw conclusions with confidence. In many fields, such results are already being produced, but computational LCO research has, thus far, been only marginally successful. The overall possibility of having such fidelity is not really in question, however, as Kim and Lee [8] have demonstrated. While this fidelity is increasing, however, the computational models are not yet at a level where they can begin to replace some of the flight tested requirements of the past. The computational cost of such fidelity cannot be ignored. The complexities of aircraft, especially those with external stores, can require far more processing time than the researcher can afford, let alone the practicing analyst. The research presented here investigates the following hypothesis: results of sufficient accuracy can be produced with an efficient computational model to estimate the probability of LCO occurring across a range of flight conditions. The most complex aeroelastic analysis will not significantly increase the confidence in the results or their utility in designing safe aircraft, only the time needed to generate those results.

To investigate this premise, this research presents the aeroelastic analysis of a linear structural model of the heavy Goland wing [9] for the onset of instability, usually called the flutter speed, with a series of different computational tools. Each successive study uses a more complex aeroelastic model. The possibility of researching LCO with each tool can be considered only after the flutter speed analysis is validated.

ZAERO® [10] is an aeroelastic modeling program that combines the necessary disciplines into a single package suited for either analysis or design. ZONA6, the subsonic unsteady aerodynamics tool within ZAERO®, is the chief tool for performing linear aeroelastic analysis of the heavy Goland wing. ZONA6 generates both steady and unsteady aerodynamic forces on bodies with external stores. According to the documentation provided with ZONA6, it provides higher accuracy than similar linear models because it uses a higher-order paneling method than the more commonly used Doublet Lattice Method [10], which is poorer at modeling complex geometries like tip stores.

The first of the nonlinear aerodynamics models employed here is ZTRAN, which is a transonic flow solver. ZTRAN, developed by ZONA Technology, Inc., was created to overlap with and extend the range of Mach numbers explored with ZONA6. It offers an approximate but simple-to-use approach to analyzing transonic aerodynamics and leaves the user with some flexibility in determining how the transonic flow is mathematically modeled. This study investigated the implications of using ZTRAN with both the Euler equations to model inviscid, transonic aerodynamics and the Navier-Stokes equations to model viscous transonic flow. Probabilistic sampling was employed to evaluate the benefits and costs of using these more complex and computationally costly models instead of the inviscid, subsonic aerodynamics in ZONA6. The data generated through sampling permitted assessment of each solver's sensitivity to small changes in the model. For simplicity, the three solvers are referred to as ZONA6; ZTRAN, Euler; and ZTRAN, Navier-Stokes. A summary of the computer software used for this research is presented in Table 1.

Table 1. Analysis Tools Used

Analysis Tool	Use
MD NASTRAN®	finite element software, a general purpose tool for structural analysis
ZONA6	subsonic unsteady aerodynamics tool within ZAERO®, chief tool for performing linear aeroelastic analysis
ZTRAN, Euler	a transonic flow solver using the Euler equations to define the Aerodynamic model with inviscid, nonlinear flow
ZTRAN, Navier Stokes	a transonic flow solver using the Navier-Stokes equations to define the Aerodynamic model with viscous, nonlinear flow

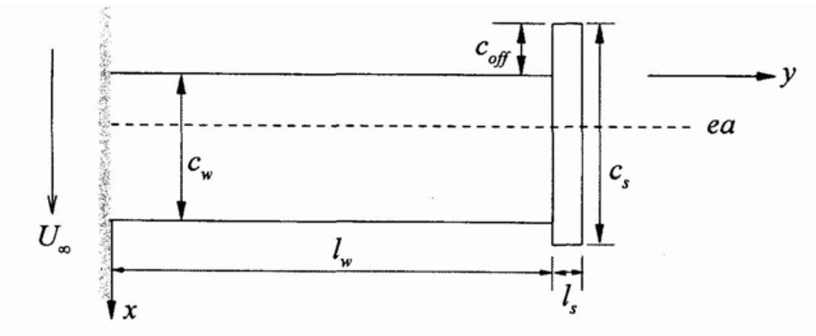
The probability of flutter was estimated with each tool by estimating the statistics of the flutter speed as a function of the Mach number. While LCO does not always occur near or above the flutter speed, this marks the transition from a stable aeroelastic system to one that could possibly exhibit dangerous motion like LCO or flutter. Once the flutter speeds' statistics were determined, they were then compared to see if the higher complexity in the more advanced computational models has a significant impact on the end results. In particular, dependable estimation of the flutter speed is a prerequisite for pursuing the estimation of LCO onset conditions.

In an environment of declining design and testing budgets, the research presented here will provide insight into using probability predictions to assess the safety of aircraft within time and resource constraints.

2 COMPUTATIONAL TESTING

2.1 Development of the Goland Wing Model

The heavy Goland wing finite element model in Figures 3 and 4 is a two-cell box structure with ribs at evenly-spaced span-wise stations. In these figures, the positive *x* direction points out the trailing edge of the wing, the positive *y* direction points from the fuselage out along the span of the wing, and the positive *z* direction is normal two the upper surface of the wing. Each rib, spar, and skin panel is modeled as an assumed material with negligible mass. The desired inertial properties of the wing are simulated with the placement and adjustment of separate concentrated masses.



c_{off} chordwise offset of tip store from wing
c_s chord length of the tip store
l_s span of the tip store
c_w chord length of the wing
U_∞ incoming air stream
l_w span of the wing
ea axis of the aerodynamic center of the wing

Figure 3. Planform Geometry of the Goland Wing [1]

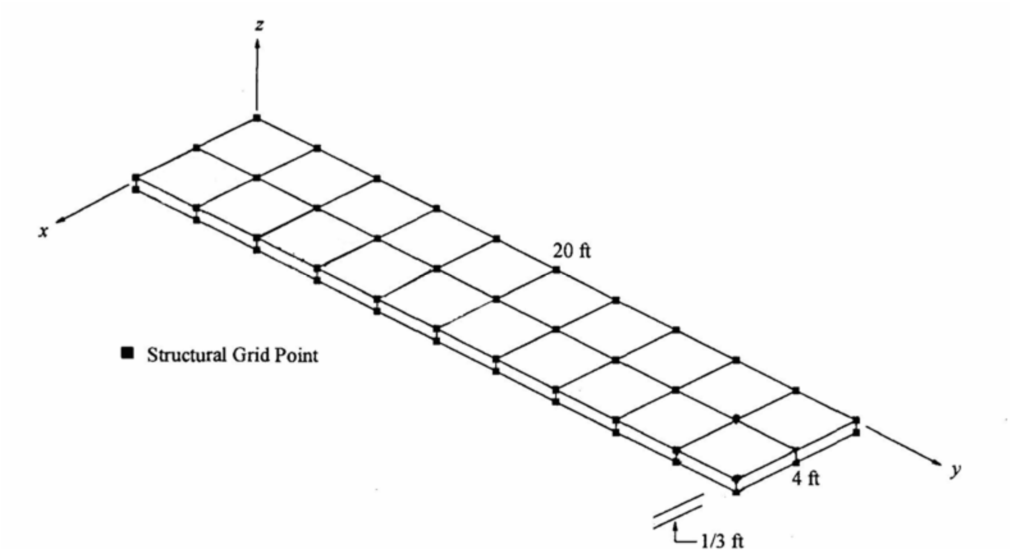


Figure 4. Structural Model of the Goland Wing [1]

The grid points shown in Figure 4 define the finite elements of the structure. These locations are linked by rod elements used to stabilize the quadrilateral shear panels, which represent the ribs and spar webs. CQUAD4 elements are used for the upper and lower skins. The Goland wing developed in the test case included the wing structure itself, as well as a simplified external store. The store is modeled as a non-structural mass of 22.5 pounds located 1.75 ft

forward of the wing’s center of gravity, and is attached to the wing by an additional rigid element. The baseline thickness of each component is presented in Table 2.

Table 2. Component Thickness Specifications

Component	Thickness (ft)
Upper Wing Spar Shell	0.0155
Lower Wing Spar Shell	0.0155
Spar	0.006
Rib	0.0347
Post	0.0008
Upper Spar Cap	0.0416
Lower Spar Cap	0.0416
Upper Rib Cap	0.0422
Lower Rib Spar Cap	0.0422

The baseline Goland Wing model was run through a modal analysis to determine the first ten natural vibration modes of the structure. The results developed for this case exactly matched those of previous studies with this model, [1] and thereby provided confidence for the continuation of the research.

2.2 Goland Wing Model Structural Analysis

For the present study of limit cycle oscillation, MSC Nastran [11] is used to assess the impact of varying the material properties on the stiffness and vibration characteristics of a structure to model manufacturing tolerances and random variations in the inertial properties, such as varying internal fuel loads.

The baseline, or mean, model is the classical Goland wing [9] with uniform material properties and component dimensions. The natural frequencies of the original baseline wing are presented in Table 3**.** Although the initial structural model was analyzed in MSC Nastran for the first 10 eigenmodes, only the first four were carried through the complete aeroelastic analysis. The results produced at the higher modes were not credible because the coarseness of the finite element mesh suggested that the higher modes were not properly resolved; therefore reliable comparisons between the aeroelastic analysis methods could only be completed with modes one through four. A finer mesh would permit further investigation of the higher level modes, but was not necessary for the goals of this effort.

Table 3. Natural Frequencies of the Baseline Case

	Mode	Baseline natural frequency (Hz)
Clean Wing	1	1.97
	2	4.05
	3	9.65
	4	13.43
Wing with External Store	1	1.69
	2	3.05
	3	9.17
	4	10.83

The first four modes of the baseline wing are depicted in Figures 5 - 8. For both the clean wing and the wing with the external store, the first mode is a pure bending mode as displayed in Figure 5; the second, third and fourth modes are combinations of bending and torsion and are displayed in Figures 6 - 8. Only the mean of the top and bottom surfaces is modeled for simplicity even though the structural study involved the complete finite element model described in section 2.1. For reference, the origin of each figure is located at the leading edge of the root chord at exactly the midpoint of the wing's thickness and the orientation of each figure matches that of Figure 4. The boundary condition applied to the wing rigidly constrained the root cross section.

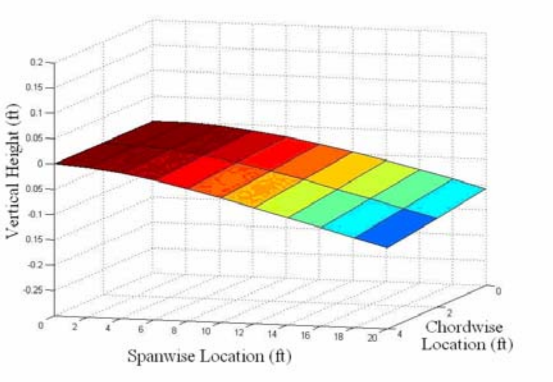


Figure 5. First Natural Mode of the Goland Wing (no external store present).

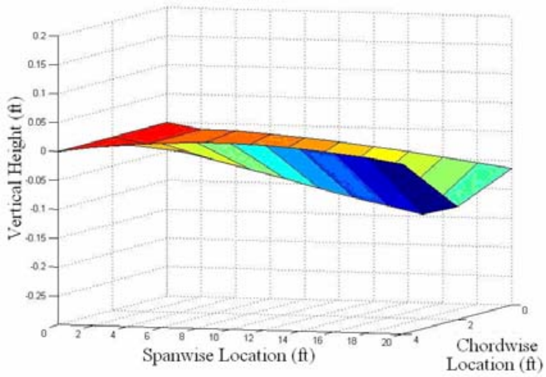


Figure 6. Second Natural Mode of the Goland Wing (with no external store)

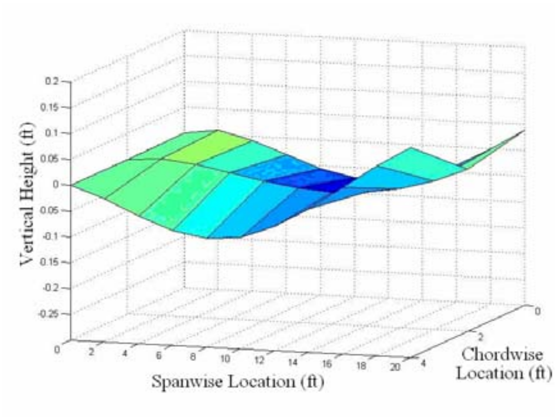


Figure 7. Third Natural Mode of the Goland Wing (with no external store)

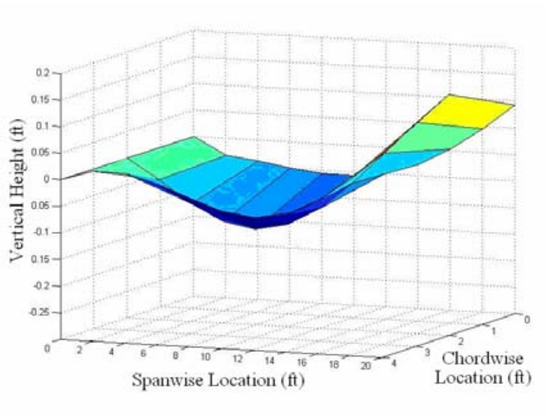


Figure 8. Fourth Natural Mode of the Goland Wing (with no external store)

2.3 Monte Carlo Simulation of the Modal Analysis

While this baseline provides a good beginning for exploration, real-world manufacturing never produces perfectly uniform structures. Alternatively, there always exists imprecision in the measured properties of a structure in practice. To mimic the effect of random variations in the structure, a process was written using FORTRAN 90 to generate a set of 2,000 variations of the Goland Wing structures. Half of this set included a tip store identical in both mass and location, while the other half did not.

The standard deviation for the component thickness parameters was set at 5% and each parameter was assumed to experience the same relative random variation in a given sample of the structure. The thickness of each component was modeled as normally distributed around the baseline specification. This collection of realizations of the structure formed the initial sample population for the Monte Carlo simulation of the wing's aeroelastic properties.

The structural study described for the baseline case was achieved for the complete set of 2,000 variations of the Goland wing. Each of the realizations was analyzed for its first four eigenmodes. For each of the four modes, histograms and normal probability plots were developed to examine the distribution of each natural frequency. Each modal frequency exhibited a unimodal distribution within 1.5% of the mean model.

Table 4 presents the mean, standard deviation, and coefficient of variation of the eigenvalue for each mode. Figure 9 presents a histogram of the variation of the first mode for the clean wing. An approximately normal distribution was observed, as can be seen by the linear trend of the corresponding normal probability plot in Figure 10. Similar results were seen for both the other three modes of the clean wing and for all four modes of the wing with the tip store.

Table 4. Statistical Summary for Eigenvalues of Goland Wing Model

	Mode	Sample Mean (hz)	Sample Standard Deviation	Sample Coefficient of Variation
Clean Wing	1	1.97	0.0274	1.39%
	2	4.048	0.0506	1.25%
	3	9.644	0.1125	1.17%
	4	13.289	0.1746	1.31%
Tip Store	1	1.69	0.0244	1.44%
	2	3.048	0.0393	1.29%
	3	9.162	0.1039	1.13%
	4	10.803	0.1399	1.29%

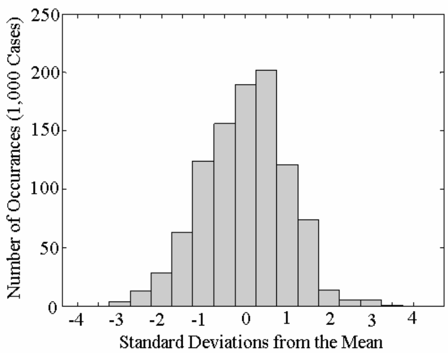


Figure 9. Histogram of Goland Wing Variation for Clean Wing, First Mode

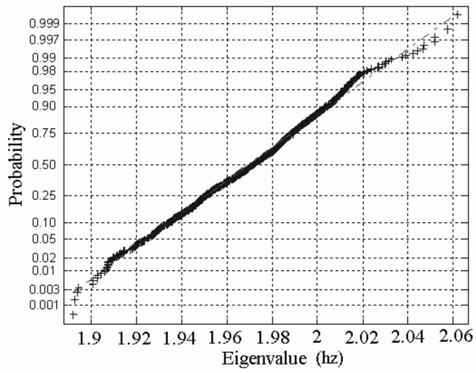


Figure 10. Normal Probability Plot for Clean Wing, 1st Mode in 1,000 Models

2.4 Aeroelastic Analysis

The linear analysis with ZONA6 determined flutter speed for each of the 2,000 wings at ten Mach numbers: 0.70, 0.80, 0.825, 0.85, 0.88, 0.90, 0.91, 0.92, 0.93, and 0.95. Because the theory underlying ZONA6 is purely subsonic, any results from above Mach 0.8 are suspect; however, these values were included in the study for continuity purposes in comparing the ZONA6 tool to the ZTRAN tool, which can more reliably simulate transonic Mach numbers. Flutter and LCO are commonly observed in the transitional, less predictable range between Mach 0.8 and 1.2 and so these numbers must remain the focus of research in this field.

Taking a cross section of the methods at Mach 0.8 which is within the comfortable Mach limitations of all three programs produces the histograms and normal probability plots presented in Figure 11. The normally distributed structural properties resulted in approximately normally distributed flutter speeds. Deviations in the Gaussian behavior in the normal probability plots are limited to the tails of the distributions. This is expected because of the limited number of samples which results in the tails being the least accurately estimated portions of the distributions.

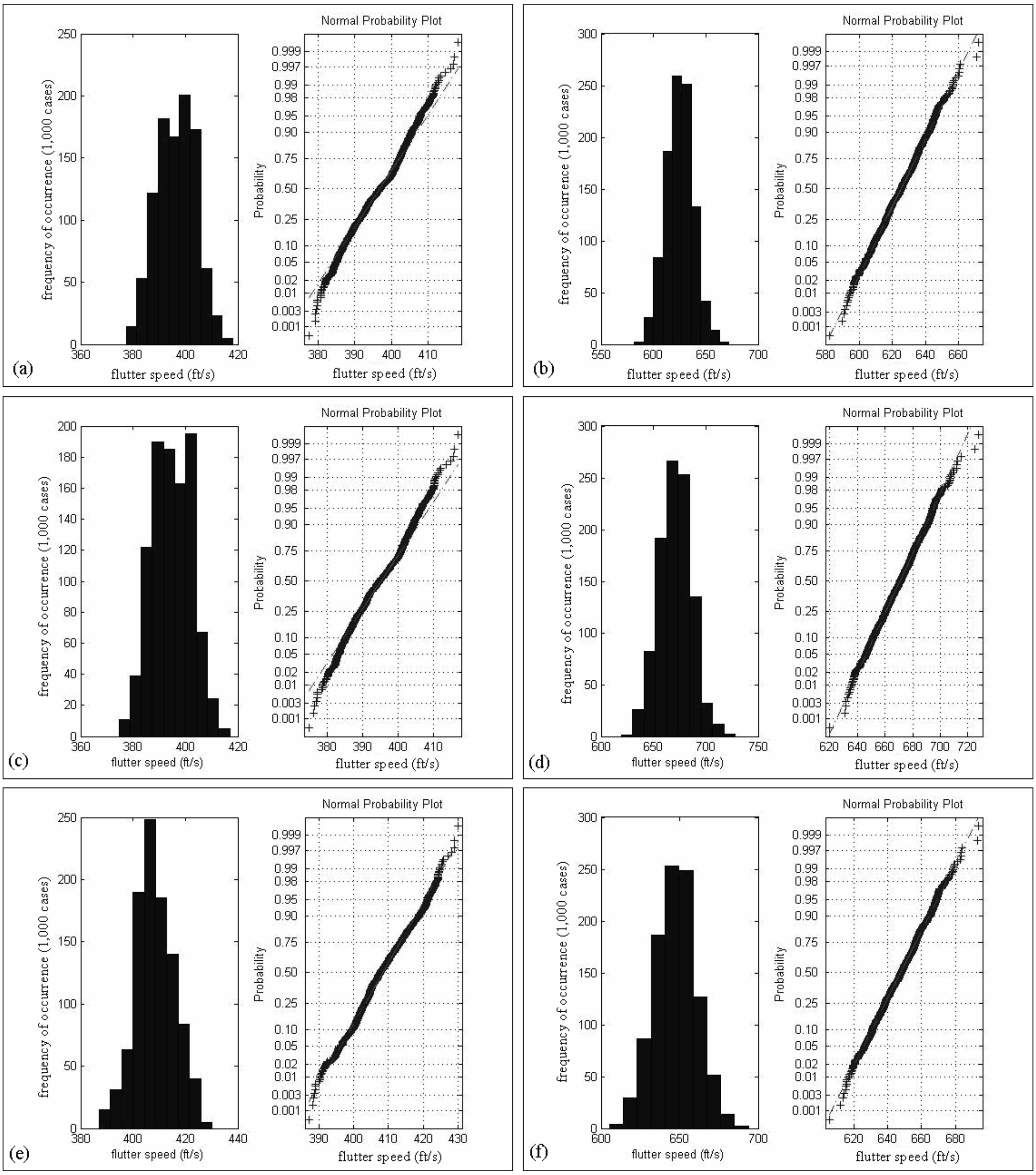


Figure 11. Histograms and Probability Plots of Flutter Speeds at Mach 0.8 for the (a) Clean Wing, ZONA6;(b) Wing with Tip Store, ZONA6; (c) Clean Wing, ZTRAN, Euler; (d) Wing with Tip Store, ZTRAN, Euler; (e) Clean Wing, ZTRAN, Navier-Stokes, and (f) Wing with Tip Store, ZTRAN, Navier-Stokes

Although the exact velocity where LCO is exhibited cannot be determined from ZONA6 or ZTRAN, the influence of structural thickness on the structural stiffness and on the flutter speed is evident. Given that wing LCO in practice is likely to start out as an aeroelastic dynamic instability, it is reasonable to expect that the distribution of LCO exhibition in the 2,000 wings would be similar to the distribution of the flutter speed. Further, at such a preliminary stage in evaluating the commercially available software for a new purpose, the

instability boundary is the starting point for determining the viability of ZAERO® as a research tool for LCO.

Table 5 presents the mean flutter speed for 1,000 cases determined by each software package over a range of Mach numbers. For the purposes of this research, "flutter speed" refers to the speed where the damping of one of the first four natural vibration modes of the wing transitions to instability. These values are also presented in Figures 12 and 13. The absence of values for ZTRAN, Euler at Mach 0.825 is not significant. These values were inadvertently omitted from the study, but the interpolation of this data point from its neighbors provides the same insight that the calculations itself would have likely provided.

Table 5. Flutter Speed in ft/s for Heavy Goland Wing Over a Range of Mach Numbers

	CLEAN WING			WING WITH TIP STORE		
Mach Number	ZONA6	ZTRAN, Euler	ZTRAN, Navier-Stokes	ZONA6	ZTRAN, Euler	ZTRAN, Navier-Stokes
0.700	428.90	428.99	436.12	647.28	662.95	659.21
0.800	396.65	394.84	408.27	625.08	670.88	647.64
0.825	385.86	not studied	398.58	618.81	not studied	646.27
0.850	373.83	364.09	386.99	612.93	902.70	648.20
0.880	358.02	351.75	366.25	608.39	1180.00	665.75
0.900	347.37	379.16	369.03	611.19	536.72	1270.20
0.910	342.89	383.31	380.17	617.11	515.97	1285.10
0.920	339.55	400.42	409.13	645.60	1360.20	445.99
0.930	338.29	414.38	468.61	710.18	345.20	366.96
0.950	344.12	423.57	412.16	1178.90	340.42	851.71

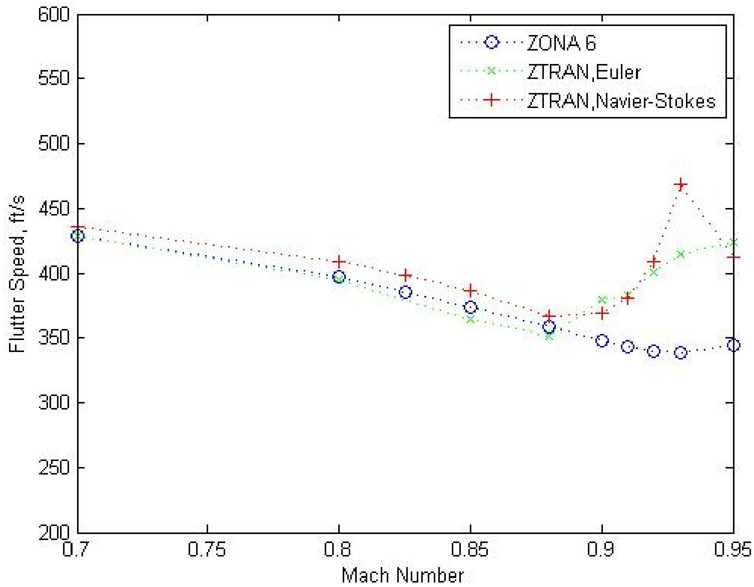


Figure 12. Flutter Speed Trends for Each Software Package Over the Range of Mach Numbers for the Heavy Goland Wing, Clean Version

Flutter speed empirically appears to decrease with increasing Mach number throughout the transonic regime to a minimum, or “dip”, and then rise in the supersonic regime [8]. For both ZTRAN tools, the onset of this dip occurs at Mach 0.88. The ZONA6 method, which was not designed for transonic research and so does not account for the theoretical flutter dip, does not exhibit the behavior at all.

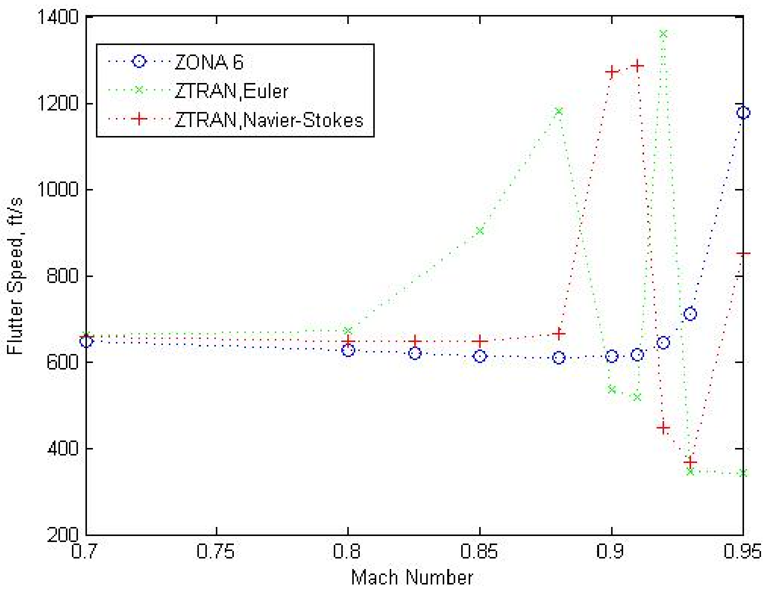


Figure 13. Flutter Speed Trends for Each Software Package Over the Range of Mach Numbers for the Heavy Goland Wing with Tip Store

From Figure 13, the expected flutter dip [8] can be observed in the ZTRAN, Navier-Stokes analysis near Mach 0.88, just where it occurred for the clean wing. The breakdown in the agreement between the three tools occurs where the upward trend in the flutter dip begins. When compared to ZTRAN, Navier-Stokes, the other two either predicted the flutter dip onset would occur prematurely at 0.8 in the case of ZTRAN, Euler, or late at 0.92 in the case of ZONA6.

Because the ZTRAN method that uses the Navier-Stokes equations to model viscous aerodynamics has the highest fidelity of any tool used in this study, it produces the most accurate and computationally expensive results. The results determined using ZONA6 and ZTRAN, Euler are compared to those from ZTRAN, Navier-Stokes results to determine the viability of each of the faster but simpler tools in determining the transition of the wing to instability.

Figure 14 illustrates the trend in percent error based on each research method across the studied range of Mach numbers for the clean wing. Both ZONA6 and ZTRAN, Euler underestimate the flutter speed up through Mach 0.88 and so would provide larger than necessary safety margins that should prevent the wing from experiencing either flutter or LCO. Above this point, even though only ZONA6 continues to underestimate the flutter speed, ZTRAN, Euler never over predicts it by more than 3%.

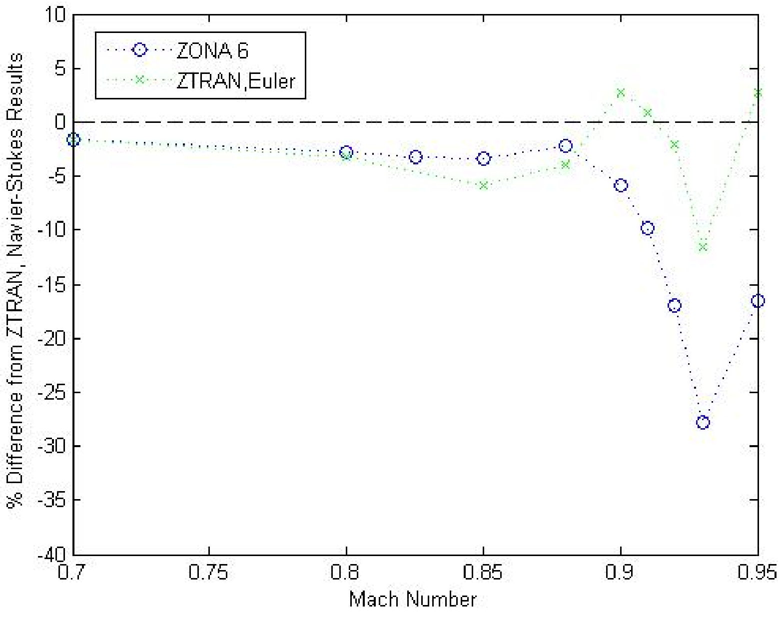


Figure 14. Percent Error from ZTRAN, Navier-Stokes for the Clean Wing

Figure 15 presents the data for the wing including the external tip store. The clear difference in method agreement between Figures 14 and 15 demonstrates why the presence of a tip store is of such concern in the study of instability and LCO. Here, once again, the ZONA6 results develop a margin of safety by under predicting flutter speeds in flight regimes between Mach 0.7 and Mach 0.88. The error in this prediction grows greater than 10% beyond Mach 0.88 where ZONA6's subsonic methods falter, largely because of the flutter dip. With the tip store

present, ZTRAN, Euler only stayed in an acceptable limit of agreement up through Mach 0.8 where the flutter dip occurs for ZTRAN, Euler in Figure 13.

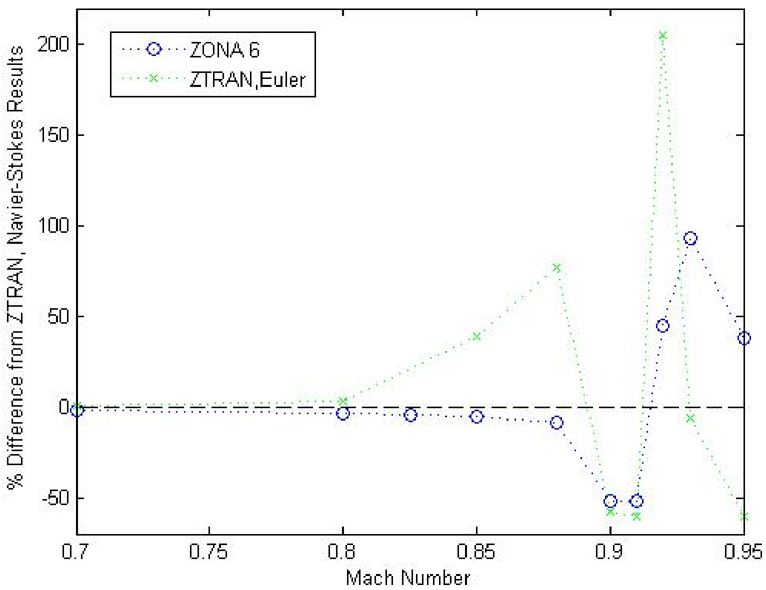


Figure 15. Percent Error from ZTRAN, Navier-Stokes for the Wing with the Tip Store

3 SUMMARY AND CONCLUSIONS

3.1 Implications of Results

For the relatively simple wing and store configurations explored here, a significant amount of computational time can be saved by using ZONA6 rather than the more computationally costly alternatives for the lower transitional Mach numbers. This tool builds a more conservative picture of the flight envelope up through Mach 0.85 that would ensure the prevention of LCO and flutter by placing a safety limit beneath the point of instability where flutter and LCO are most likely to occur. Further, the limit would be within 5% of the values predicted by the most complicated of the tools used in this study.

ZTRAN, Euler is equally useful for a clean wing from Mach 0.7 through Mach 0.95. It is more computationally costly than ZONA6; however, it also provided extended functionality by following the ZTRAN, Navier-Stokes trends up into the higher Mach numbers.

When an external store is present at Mach numbers greater than 0.9, however, the computational cost to produce the viscous results with ZTRAN coupled with the Navier-Stokes equations is necessary for confidence in the results. These transonic speeds were not accurately or even predictably modeled by either of the faster alternatives because discrepancies in flutter dip prediction; the error percentages quickly grow to even 16 times what they were between Mach 0.7 and 0.88. This observation is supported by Marsden and Price [12] who concluded that full Navier-Stokes solvers are necessary for the details of LCO or instability predictions even for the two dimensional airfoil.

3.2 Further Research

The properties of the external store are a point of interest for future research. Variation in either the location or mass of the store could alter the simulated response significantly, potentially developing deeper insight into the factors that promote limit cycle oscillation.

The small (<1.5%) standard deviations in the eigenvalues of the wing determined in the structural study point to the need for future analysis of the effects of mass distribution, rather than the stiffness of the structure that the thickness of the components controls. There is an apparent insensitivity to the thickness variation because its standard deviation is more than three times greater than the resulting standard deviations in the eigenvalues of any of the first four natural modes.

Further, the Computational Aeroelasticity Program-Transonic Small Disturbance (CAP-TSDv) developed by NASA Langley Research Center implements transonic small-disturbance theory coupled with a boundary layer model to approximate viscous effects. This theory provides a stepping stone between the ZTRAN environment and the full computational fluid dynamics programs. CAP-TSDv is currently being integrated extended through the OVERCAP software developed cooperatively by ZONA and the Air Force Research Laboratory. This helps to simplify communication between NASTRAN and CAP-TSDv. It is similar in format to both ZAERO and NASTRAN. Probabilistic simulations conducted through OVERCAP would be more computationally costly than the research described here because OVERCAP generates results based on a more precise and higher-fidelity model of the flow field than either ZONA6 or ZTRAN. OVERCAP generates time domain estimates of aeroelastic response that should lead to insight into LCO rather than the simplified instability boundary analysis conducted thus far.

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APPENDIX A: GLOSSARY OF TERMS

Aeroelasticity	The study of the interactions between aerodynamic, structural, and inertial forces acting within a system
Clean Wing	That version of the wing where no external stores are present
Computational Cost	Amount of time a computational process requires
Doublet Lattice Method	A method for modeling the aerodynamics of a system as a lattice of doublets where a doublet is a co-located source-sink pair
Eigenmode	Natural vibrational mode, or shape, of a system
Eigenvalue	Frequency of a natural vibration mode within a system
Euler Equations	Governing equations that describe fluid dynamics when viscous effects are ignored
External Stores	Anything attached to an aircraft wing, for example external fuel tanks or air-to-air missiles
Finite Element Analysis	Computational analysis to obtain approximate solutions by representing a more complex model as the collection of many discrete subsections of the larger component
Flutter	Neutrally stable oscillation of an aircraft component, typically the wing, owing to aeroelastic interactions. These severe vibrations can cause the separation of the component from the aircraft and overall structural failure.
Flutter Speed	The onset of instability in the aeroelastic model; the speed where the structural damping needed to maintain neutrally stable motion at a given dynamic pressure transitions to positive in at least one vibration mode. Does not necessarily mark the advent of either flutter or LCO
Goland Wing Model	A simple wing model produced in the 1950s by Martin Goland for flutter research; see reference [9] for more information.
Inertial Forces	Sometimes called "fictional forces," inertial forces are those forces that act on a system when it is considered within its own accelerating reference system. These forces are the reaction of the body to its own accelerations. A common example of such a force is the centrifugal force of rotational motion, which seems to push the accelerated body toward the center of rotation.
Limit Cycle Oscillation	Self-sustained, stable oscillation of an aircraft or structural component produced by aeroelastic interactions. These moderate to mild vibrations put unexpected fatigue on structural components.
Linear Structural Analysis	Analysis which makes an assumption that a structure will behave linearly in response to external loads
Lower Rib Cap	Elements that run along the lower surfaces of the ribs

Lower Spar Cap	Elements that run along the lower surfaces of the spars
Lower Wing Skin	Material that covers the bottom surface of the wing box.
MD NASTRAN®	Finite Element Analysis software produced by the MSC corporation for broad use by all engineering disciplines to perform simulations
Navier-Stokes Equations	Governing equations that describe the dynamics of Newtonian, Stokesian viscous flow or how the velocity, pressure, temperature, and density of a moving fluid are related when the effects of viscosity are included
Outlier	A value that lies significantly away from an accepted or mean value; in the present study, any value more than two standard deviations away from the accepted or mean value
Posts	The vertical components of the wing finite element model that connect the upper and lower wing surfaces together.
Predictive Accuracy	How closely computational results resemble real-world behavior
Ribs	Components that run the length of the wing parallel to the wing chord line or the fuselage chord line drawn from the aircraft nose to its tail.
Spars	Components that run the span of a wing from the root (where the fuselage would be) to the tip
Structural stiffness	Static resistance of a structure to deflection from equilibrium
Tip Store	An external store located at the edge of a wing span that is furthest from the fuselage
Transonic airflow	Airflow characterized by a Mach number in the transitional range between subsonic and supersonic, typically $0.8<M<1.2$
Transonic Small Disturbance	A simplified model of transonic flight that assumes inviscid behavior and small variations from free-stream conditions
Upper Rib Cap	Elements that run along the upper surfaces of the ribs
Upper Spar Cap	Elements that run along the upper surfaces of the spars
Upper Wing Skin	Material that covers the top surface of the wing box.
Viscosity	A measure of a fluid's resistance to deformation by shear (friction) forces
ZAERO®	An aeroelastic modeling program produced by ZONA Technologies®
ZONA6	the subsonic unsteady aerodynamics tool within ZAERO®
ZTRAN	a transonic flow solver within ZAERO®

APPENDIX B: Bulk Data File of Cleanwing.bdf Model

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$.......2.......3.......4.......5.......6.......7.......8.......9.......10.
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$  RBARS at Root
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....$
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RBAR    101     100     10001   123456                  123456
RBAR    102     100     10002   123456                  123456
RBAR    200     100     20000   123456                  123456
RBAR    201     100     20001   123456                  123456
RBAR    202     100     20002   123456                  123456
$  Upper Surface Grids
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....$
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GRID    10002           4.0     0.0     0.16667
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GRID    10101           2.0     2.0     0.16667
GRID    10102           4.0     2.0     0.16667
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GRID    10201           2.0     4.0     0.16667
GRID    10202           4.0     4.0     0.16667
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GRID    10302           4.0     6.0     0.16667
GRID    10400           0.0     8.0     0.16667
GRID    10401           2.0     8.0     0.16667
GRID    10402           4.0     8.0     0.16667
GRID    10500           0.0     10.0    0.16667
GRID    10501           2.0     10.0    0.16667
GRID    10502           4.0     10.0    0.16667
GRID    10600           0.0     12.0    0.16667
GRID    10601           2.0     12.0    0.16667
GRID    10602           4.0     12.0    0.16667
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GRID    10701           2.0     14.0    0.16667
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GRID    10801           2.0     16.0    0.16667
GRID    10802           4.0     16.0    0.16667
GRID    10900           0.0     18.0    0.16667
GRID    10901           2.0     18.0    0.16667
GRID    10902           4.0     18.0    0.16667
GRID    11000           0.0     20.0    0.16667
GRID    11001           2.0     20.0    0.16667
GRID    11002           4.0     20.0    0.16667
$  Lower Surface Grids
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....$
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GRID    20001           2.0     0.0     -0.16667
GRID    20002           4.0     0.0     -0.16667
GRID    20100           0.0     2.0     -0.16667
```

```
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GRID    20201           2.0     4.0     -0.16667
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GRID    20301           2.0     6.0     -0.16667
GRID    20302           4.0     6.0     -0.16667
GRID    20400           0.0     8.0     -0.16667
GRID    20401           2.0     8.0     -0.16667
GRID    20402           4.0     8.0     -0.16667
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GRID    20501           2.0     10.0    -0.16667
GRID    20502           4.0     10.0    -0.16667
GRID    20600           0.0     12.0    -0.16667
GRID    20601           2.0     12.0    -0.16667
GRID    20602           4.0     12.0    -0.16667
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GRID    20701           2.0     14.0    -0.16667
GRID    20702           4.0     14.0    -0.16667
GRID    20800           0.0     16.0    -0.16667
GRID    20801           2.0     16.0    -0.16667
GRID    20802           4.0     16.0    -0.16667
GRID    20900           0.0     18.0    -0.16667
GRID    20901           2.0     18.0    -0.16667
GRID    20902           4.0     18.0    -0.16667
GRID    21000           0.0     20.0    -0.16667
GRID    21001           2.0     20.0    -0.16667
GRID    21002           4.0     20.0    -0.16667
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CQUAD4  210100  210100  10100   10101   10201   10200
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CQUAD4  210401  210401  10401   10402   10502   10501
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CQUAD4  210800  210800  10800   10801   10901   10900
CQUAD4  210801  210801  10801   10802   10902   10901
CQUAD4  210900  210900  10900   10901   11001   11000
CQUAD4  210901  210901  10901   10902   11002   11001
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....$
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CQUAD4  220101  220101  20101   20102   20202   20201
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CQUAD4  220401  220401  20401   20402   20502   20501
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CQUAD4  220600  220600  20600   20601   20701   20700
CQUAD4  220601  220601  20601   20602   20702   20701
CQUAD4  220700  220700  20700   20701   20801   20800
CQUAD4  220701  220701  20701   20702   20802   20801
CQUAD4  220800  220800  20800   20801   20901   20900
CQUAD4  220801  220801  20801   20802   20902   20901
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CQUAD4  220901  220901  20901   20902   21002   21001
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....$
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CSHEAR  230004  230004  10400   10500   20500   20400
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CSHEAR  230102  230102  10201   10301   20301   20201
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CSHEAR  230106  230106  10601   10701   20701   20601
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```
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CSHEAR  240600  240600  10600   10601   20601   20600
CSHEAR  240601  240601  10601   10602   20602   20601
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CROD    110002  110002  10002   20002
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CROD    110101  110101  10101   20101
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CROD    110200  110200  10200   20200
CROD    110201  110201  10201   20201
CROD    110202  110202  10202   20202
CROD    110300  110300  10300   20300
CROD    110301  110301  10301   20301
CROD    110302  110302  10302   20302
CROD    110400  110400  10400   20400
CROD    110401  110401  10401   20401
CROD    110402  110402  10402   20402
CROD    110500  110500  10500   20500
CROD    110501  110501  10501   20501
CROD    110502  110502  10502   20502
CROD    110600  110600  10600   20600
CROD    110601  110601  10601   20601
CROD    110602  110602  10602   20602
CROD    110700  110700  10700   20700
CROD    110701  110701  10701   20701
CROD    110702  110702  10702   20702
CROD    110800  110800  10800   20800
CROD    110801  110801  10801   20801
CROD    110802  110802  10802   20802
CROD    110900  110900  10900   20900
CROD    110901  110901  10901   20901
CROD    110902  110902  10902   20902
CROD    111000  111000  11000   21000
CROD    111001  111001  11001   21001
CROD    111002  111002  11002   21002
$ Upper Spar Caps
$.......2.......3.......4.......5.......6.......7.......8.......9.......10.
....$
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CROD    120001  120001  10100   10200
CROD    120002  120002  10200   10300
CROD    120003  120003  10300   10400
CROD    120004  120004  10400   10500
```

```
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CROD    120007  120007  10700   10800
CROD    120008  120008  10800   10900
CROD    120009  120009  10900   11000
CROD    120100  120100  10001   10101
CROD    120101  120101  10101   10201
CROD    120102  120102  10201   10301
CROD    120103  120103  10301   10401
CROD    120104  120104  10401   10501
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CROD    120201  120201  10102   10202
CROD    120202  120202  10202   10302
CROD    120203  120203  10302   10402
CROD    120204  120204  10402   10502
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CROD    120206  120206  10602   10702
CROD    120207  120207  10702   10802
CROD    120208  120208  10802   10902
CROD    120209  120209  10902   11002
$ Lower Spar Caps
$.......2.......3.......4.......5.......6.......7.......8.......9.......10.
....$
CROD    130000  130000  20000   20100
CROD    130001  130001  20100   20200
CROD    130002  130002  20200   20300
CROD    130003  130003  20300   20400
CROD    130004  130004  20400   20500
CROD    130005  130005  20500   20600
CROD    130006  130006  20600   20700
CROD    130007  130007  20700   20800
CROD    130008  130008  20800   20900
CROD    130009  130009  20900   21000
CROD    130100  130100  20001   20101
CROD    130101  130101  20101   20201
CROD    130102  130102  20201   20301
CROD    130103  130103  20301   20401
CROD    130104  130104  20401   20501
CROD    130105  130105  20501   20601
CROD    130106  130106  20601   20701
CROD    130107  130107  20701   20801
CROD    130108  130108  20801   20901
CROD    130109  130109  20901   21001
CROD    130200  130200  20002   20102
CROD    130201  130201  20102   20202
CROD    130202  130202  20202   20302
CROD    130203  130203  20302   20402
CROD    130204  130204  20402   20502
CROD    130205  130205  20502   20602
CROD    130206  130206  20602   20702
CROD    130207  130207  20702   20802
CROD    130208  130208  20802   20902
CROD    130209  130209  20902   21002
$ Upper Rib Caps
```

```
$.......2.......3.......4.......5.......6.......7.......8.......9.......10.
....$
CROD    140000  140000  10000   10001
CROD    140001  140001  10001   10002
CROD    140100  140100  10100   10101
CROD    140101  140101  10101   10102
CROD    140200  140200  10200   10201
CROD    140201  140201  10201   10202
CROD    140300  140300  10300   10301
CROD    140301  140301  10301   10302
CROD    140400  140400  10400   10401
CROD    140401  140401  10401   10402
CROD    140500  140500  10500   10501
CROD    140501  140501  10501   10502
CROD    140600  140600  10600   10601
CROD    140601  140601  10601   10602
CROD    140700  140700  10700   10701
CROD    140701  140701  10701   10702
CROD    140800  140800  10800   10801
CROD    140801  140801  10801   10802
CROD    140900  140900  10900   10901
CROD    140901  140901  10901   10902
CROD    141000  141000  11000   11001
CROD    141001  141001  11001   11002
$ Lower Rib Caps
$.......2.......3.......4.......5.......6.......7.......8.......9.......10.
....$
CROD    150000  150000  20000   20001
CROD    150001  150001  20001   20002
CROD    150100  150100  20100   20101
CROD    150101  150101  20101   20102
CROD    150200  150200  20200   20201
CROD    150201  150201  20201   20202
CROD    150300  150300  20300   20301
CROD    150301  150301  20301   20302
CROD    150400  150400  20400   20401
CROD    150401  150401  20401   20402
CROD    150500  150500  20500   20501
CROD    150501  150501  20501   20502
CROD    150600  150600  20600   20601
CROD    150601  150601  20601   20602
CROD    150700  150700  20700   20701
CROD    150701  150701  20701   20702
CROD    150800  150800  20800   20801
CROD    150801  150801  20801   20802
CROD    150900  150900  20900   20901
CROD    150901  150901  20901   20902
CROD    151000  151000  21000   21001
CROD    151001  151001  21001   21002
$ Material Data
$.......2.......3.......4.......5.......6.......7.......8.......9.......10.
....$
$  Eastep's Material
MAT1    101     1.4976E95.616E8         0.000001
$ Upper Surface Concentrated Masses
$.......2.......3.......4.......5.......6.......7.......8.......9.......10.
....$
CONM2   10000   10000           0.9825
CONM2   10001   10001           1.9721
```

```
CONM2   10002   10002           2.6699
CONM2   10100   10100           1.9650
CONM2   10101   10101           3.9442
CONM2   10102   10102           5.3398
CONM2   10200   10200           1.9650
CONM2   10201   10201           3.9442
CONM2   10202   10202           5.3398
CONM2   10300   10300           1.9650
CONM2   10301   10301           3.9442
CONM2   10302   10302           5.3398
CONM2   10400   10400           1.9650
CONM2   10401   10401           3.9442
CONM2   10402   10402           5.3398
CONM2   10500   10500           1.9650
CONM2   10501   10501           3.9442
CONM2   10502   10502           5.3398
CONM2   10600   10600           1.9650
CONM2   10601   10601           3.9442
CONM2   10602   10602           5.3398
CONM2   10700   10700           1.9650
CONM2   10701   10701           3.9442
CONM2   10702   10702           5.3398
CONM2   10800   10800           1.9650
CONM2   10801   10801           3.9442
CONM2   10802   10802           5.3398
CONM2   10900   10900           1.9650
CONM2   10901   10901           3.9442
CONM2   10902   10902           5.3398
CONM2   11000   11000           0.9825
CONM2   11001   11001           1.9721
CONM2   11002   11002           2.6699
$ Lower Surface Concentrated Masses
$.......2.......3.......4.......5.......6.......7.......8.......9.......10.
....$
CONM2   20000   20000           0.9825
CONM2   20001   20001           1.9721
CONM2   20002   20002           2.6699
CONM2   20100   20100           1.9650
CONM2   20101   20101           3.9442
CONM2   20102   20102           5.3398
CONM2   20200   20200           1.9650
CONM2   20201   20201           3.9442
CONM2   20202   20202           5.3398
CONM2   20300   20300           1.9650
CONM2   20301   20301           3.9442
CONM2   20302   20302           5.3398
CONM2   20400   20400           1.9650
CONM2   20401   20401           3.9442
CONM2   20402   20402           5.3398
CONM2   20500   20500           1.9650
CONM2   20501   20501           3.9442
CONM2   20502   20502           5.3398
CONM2   20600   20600           1.9650
CONM2   20601   20601           3.9442
CONM2   20602   20602           5.3398
CONM2   20700   20700           1.9650
CONM2   20701   20701           3.9442
CONM2   20702   20702           5.3398
CONM2   20800   20800           1.9650
```

CONM2	20801	20801	3.9442
CONM2	20802	20802	5.3398
CONM2	20900	20900	1.9650
CONM2	20901	20901	3.9442
CONM2	20902	20902	5.3398
CONM2	21000	21000	0.9825
CONM2	21001	21001	1.9721
CONM2	21002	21002	2.6699

APPENDIX C: Bulk Data File of Tipstoremass.bdf Model

```
$  Tip Missile Model
$.......2.......3.......4.......5.......6.......7.......8.......9.......10.....$
GRID    30100           -3.0    20.5    0.0
GRID    30101           1.0     20.5    0.0
GRID    30102           2.0     20.5    0.0
GRID    30103           3.0     20.5    0.0
GRID    30104           7.0     20.5    0.0
RBAR    310     30101   30100   123456                  123456
RBAR    311     30102   30101   123456                  123456
RBAR    312     30102   30103   123456                  123456
RBAR    313     30103   30104   123456                  123456
$Tip MASS CONM2
CONM2   30102   30102           22.4980  -1.75  0.0     0.0             +M11003
+M11003                 50.3396
$  Connection to Tip Rib
RBAR    320     30001   30102   123456                  123456
$  Tip Rib Store Connection Points
$.......2.......3.......4.......5.......6.......7.......8.......9.......10.....$
GRID    30000           1.0     20.0    0.0
GRID    30001           2.0     20.0    0.0
GRID    30002           3.0     20.0    0.0
$.......2.......3.......4.......5.......6.......7.......8.......9.......10.....$
RBE3    300             30000   123456  1.0     123     11000   11001   +BE3300
+BE3300 21000   21001
$.......2.......3.......4.......5.......6.......7.......8.......9.......10.....$
RBE3    301             30002   123456  1.0     123     11001   11002   +BE3301
+BE3301 21001   21002
$.......2.......3.......4.......5.......6.......7.......8.......9.......10.....$
RBE3    302             30001   123456  1.0     1234    30000   30002
```

APPENDIX D: Example Input File for MD NASTRAN®

```
$  Built-up Goland Wing Model
$
ASSIGN OUTPUT4='testcw.mgh' STATUS=UNKNOWN UNIT=12 FORM=FORMATTED
SOL 103  $ Normal Modes Analysis
COMPILE SEMODES SOUIN=MSCSOU LIST NOREF $
ALTER 359 $
MPYAD MGG,PHG,/MGH $
OUTPUT4 MGH///12/2//9$
ENDALTER
CEND
$
TITLE = BUILT-UP GOLAND WING MODEL
SUBTITLE = CLEAN WING NORMAL MODES ANALYSIS
$
  METHOD = 10   $ SELECT EIGR ENTRY
  SPC = 10      $ SELECT SPC
$
$  SELECT OUTPUT
  DISPLACEMENT = ALL
$
BEGIN BULK
$  Solution Control Data
$.......2.......3.......4.......5.......6.......7.......8.......9.......10.....$
EIGRL   10      0.0             10
$EIGRL   10      0.0     30.0
SPC1    10      123456  100
$ PARAM   GRDPNT  100
$ PARAM   POST    0
$
INCLUDE 'CleanWing.bdf'
$INCLUDE 'Tipstoremass.bdf'
$
ENDDATA
```

APPENDIX E: Example Input File for ZAERO® ZONA6

```
$ ... Executive Control
ASSIGN FEM=basecw0000.f06, PRINT=0, FORM=MSC, BOUND=SYM
ASSIGN MATRIX =basecw0000.mgh, FORM=FORMAT,   MNAME=SMGH, PRINT=0
MEMORY 800MB
$SOL -2
CEND
$ ... Case Control
TITLE   = AEROELASTIC ANALYSIS OF Goland Wing
ECHO    = SORT
    SUBCASE = 70
      SUBTITLE =  LINEAR FLUTTER ANALYSIS
      LABEL    =  MACH NUMBER =  0.70, NON MATCHED-POINT FLUTTER ANALYSIS
      FLUTTER  = 70
    SUBCASE = 80
      SUBTITLE =  LINEAR FLUTTER ANALYSIS
      LABEL    =  MACH NUMBER =  0.80, NON MATCHED-POINT FLUTTER ANALYSIS
      FLUTTER  = 80
    SUBCASE = 825
      SUBTITLE =  LINEAR FLUTTER ANALYSIS
      LABEL    =  MACH NUMBER =  0.825, NON MATCHED-POINT FLUTTER ANALYSIS
      FLUTTER  = 825
$     SUBCASE = 85
$      SUBTITLE =  LINEAR FLUTTER ANALYSIS
$     LABEL    =  MACH NUMBER =  0.85, NON MATCHED-POINT FLUTTER ANALYSIS
$      FLUTTER  = 85
    SUBCASE = 88
      SUBTITLE =  LINEAR FLUTTER ANALYSIS
      LABEL    =  MACH NUMBER =  0.88, NON MATCHED-POINT FLUTTER ANALYSIS
      FLUTTER  = 88
     SUBCASE = 90
      SUBTITLE =  LINEAR FLUTTER ANALYSIS
      LABEL    =  MACH NUMBER =  0.90, NON MATCHED-POINT FLUTTER ANALYSIS
      FLUTTER  = 90
    SUBCASE = 91
      SUBTITLE =  LINEAR FLUTTER ANALYSIS
      LABEL    =  MACH NUMBER =  0.91, NON MATCHED-POINT FLUTTER ANALYSIS
      FLUTTER  = 91
    SUBCASE = 92
      SUBTITLE =  LINEAR FLUTTER ANALYSIS
      LABEL    =  MACH NUMBER =  0.92, NON MATCHED-POINT FLUTTER ANALYSIS
      FLUTTER  = 92
    SUBCASE = 93
      SUBTITLE =  LINEAR FLUTTER ANALYSIS
      LABEL    =  MACH NUMBER =  0.93, NON MATCHED-POINT FLUTTER ANALYSIS
      FLUTTER  = 93
    SUBCASE = 95
      SUBTITLE =  LINEAR FLUTTER ANALYSIS
      LABEL    =  MACH NUMBER =  0.95, NON MATCHED-POINT FLUTTER ANALYSIS
      FLUTTER  = 95
$ ... Bulk Data Deck
BEGIN BULK
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
PLTVG        70      70            EQUV  TABLE  CBZ60700000.dat
PLTVG        80      80            EQUV  TABLE  CBZ60800000.dat
PLTVG       825     825            EQUV  TABLE  CBZ68250000.dat
PLTVG        85      85            EQUV  TABLE  CBZ60850000.dat
PLTVG     88     88                EQUV  TABLE  CBZ60880000.dat
PLTVG        90      90            EQUV  TABLE  CBZ60900000.dat
PLTVG        91      91            EQUV  TABLE  CBZ60910000.dat
PLTVG        92      92            EQUV  TABLE  CBZ60920000.dat
PLTVG        93      93            EQUV  TABLE  CBZ60930000.dat
PLTVG        95      95            EQUV  TABLE  CBZ60950000.dat
include 'baseaero.inp'
include 'alt_mach_mkz_fluts.inp'
ENDDATA
$ alt_mach_mkz_fluta.inp
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
$       IDMK    MACH    METHOD  IDFLT   SAVE    <--FILENAME-->  PRINT   $
$       FREQ1   FREQ2   ETC
$MKAEROZ 70      0.70    0       70      SAVE    CBZ60700.AIC     0       +MK1
MKAEROZ 70      0.70    0       70      ACQUIRE CBZ60700.AIC     0       +MK1
```

```
+MK1    0.025   0.075    0.15    0.3      0.5    0.75    1.0      1.2     +
+        1.6     2.0
TRIMFLT 70      0       1.0
FLUTTER 70      SYMML   70              0       0       0
FIXMDEN 70      70      0.002377  LBF/      FT                          +FIX701
+FIX701 300.0   320.0   340.0   360.0   380.0   400.0   420.0   440.0   +FIX702
+FIX702 460.0   480.0   500.0   520.0   540.0   560.0   580.0   600.0   +FIX703
+FIX703 620.0   640.0   660.0   680.0   700.0   720.0   740.0   760.0   +FIX704
+FIX704 780.0   800.0   820.0   840.0   860.0   880.0   900.0   920.0   +FIX705
+FIX705 940.0   960.0   980.0   1000.0  1020.0  1040.0  1060.0  1080.0  +FIX706
+FIX706 1100.0  1120.0  1140.0  1160.0  1180.0  1200.0  1220.0  1240.0  +FIX707
+FIX707 1260.0  1280.0  1300.0  1320.0  1340.0  1360.0  1380.0  1400.0  +FIX708
+FIX708 1420.0  1440.0  1460.0  1480.0  1500.0
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
$MKAEROZ 80      0.80    0       80      SAVE    CBZ60800.AIC     0       +MK1
MKAEROZ 80      0.80    0       80      ACQUIRE CBZ60800.AIC     0       +MK1
+MK1    0.025   0.075    0.15    0.3      0.5    0.75    1.0      1.2     +
+        1.6     2.0
TRIMFLT 80      0       1.0
FLUTTER 80      SYMML   80              0       0       0
FIXMDEN 80      80      0.002377   LBF/    FT                           +FIX701
+FIX701 300.0   320.0   340.0   360.0   380.0   400.0   420.0   440.0   +FIX702
+FIX702 460.0   480.0   500.0   520.0   540.0   560.0   580.0   600.0   +FIX703
+FIX703 620.0   640.0   660.0   680.0   700.0   720.0   740.0   760.0   +FIX704
+FIX704 780.0   800.0   820.0   840.0   860.0   880.0   900.0   920.0   +FIX705
+FIX705 940.0   960.0   980.0   1000.0  1020.0  1040.0  1060.0  1080.0  +FIX706
+FIX706 1100.0  1120.0  1140.0  1160.0  1180.0  1200.0  1220.0  1240.0  +FIX707
+FIX707 1260.0  1280.0  1300.0  1320.0  1340.0  1360.0  1380.0  1400.0  +FIX708
+FIX708 1420.0  1440.0  1460.0  1480.0  1500.0
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
MKAEROZ 825      0.825   0       825      SAVE    CBZ60825.AIC     0       +MK1
$MKAEROZ 825      0.825   0       825    ACQUIRE CBZ60825.AIC       0       +MK1
+MK1    0.025   0.075    0.15    0.3      0.5    0.75    1.0      1.2     +
+        1.6     2.0
TRIMFLT 825      0      1.0
FLUTTER 825      SYMML  825             0       0       0
FIXMDEN 825      825    0.002377   LBF/    FT                           +FIX701
+FIX701 300.0   320.0   340.0   360.0   380.0   400.0   420.0   440.0   +FIX702
+FIX702 460.0   480.0   500.0   520.0   540.0   560.0   580.0   600.0   +FIX703
+FIX703 620.0   640.0   660.0   680.0   700.0   720.0   740.0   760.0   +FIX704
+FIX704 780.0   800.0   820.0   840.0   860.0   880.0   900.0   920.0   +FIX705
+FIX705 940.0   960.0   980.0   1000.0  1020.0  1040.0  1060.0  1080.0  +FIX706
+FIX706 1100.0  1120.0  1140.0  1160.0  1180.0  1200.0  1220.0  1240.0  +FIX707
+FIX707 1260.0  1280.0  1300.0  1320.0  1340.0  1360.0  1380.0  1400.0  +FIX708
+FIX708 1420.0  1440.0  1460.0  1480.0  1500.0
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
MKAEROZ 85      0.85    0       85      SAVE    CBZ60850.AIC     0       +MK1
$MKAEROZ  85      0.85    0       85     ACQUIRE  CBZ60850.AIC     0       +MK1
+MK1    0.025   0.075    0.15    0.3      0.5    0.75    1.0      1.2     +
+        1.6     2.0
TRIMFLT 85      0       1.0
FLUTTER 85      SYMML   85              0       0       0
FIXMDEN 85      85      0.002377   LBF/     FT                          +FIX701
+FIX701 300.0   320.0   340.0   360.0   380.0   400.0   420.0   440.0   +FIX702
+FIX702 460.0   480.0   500.0   520.0   540.0   560.0   580.0   600.0   +FIX703
+FIX703 620.0   640.0   660.0   680.0   700.0   720.0   740.0   760.0   +FIX704
+FIX704 780.0   800.0   820.0   840.0   860.0   880.0   900.0   920.0   +FIX705
+FIX705 940.0   960.0   980.0   1000.0  1020.0  1040.0  1060.0  1080.0  +FIX706
+FIX706 1100.0  1120.0  1140.0  1160.0  1180.0  1200.0  1220.0  1240.0  +FIX707
+FIX707 1260.0  1280.0  1300.0  1320.0  1340.0  1360.0  1380.0  1400.0  +FIX708
+FIX708 1420.0  1440.0  1460.0  1480.0  1500.0
$$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
$$MKAEROZ 88      0.88    0       88      SAVE     CBZ60880.AIC     0       +MK1
MKAEROZ 88      0.88    0       88      ACQUIRE CBZ60880.AIC     0       +MK1
+MK1    0.025   0.075    0.15    0.3      0.5    0.75    1.0      1.2     +
+        1.6     2.0
TRIMFLT 88      0       1.0
FLUTTER 88      SYMML   88              0       0       0
FIXMDEN 88      88      0.002377  LBF/      FT                          +FIX701
+FIX701 300.0   320.0   340.0   360.0   380.0   400.0   420.0   440.0   +FIX702
+FIX702 460.0   480.0   500.0   520.0   540.0   560.0   580.0   600.0   +FIX703
+FIX703 620.0   640.0   660.0   680.0   700.0   720.0   740.0   760.0   +FIX704
+FIX704 780.0   800.0   820.0   840.0   860.0   880.0   900.0   920.0   +FIX705
```

```
+FIX705 940.0   960.0   980.0   1000.0  1020.0  1040.0  1060.0  1080.0  +FIX706
+FIX706 1100.0  1120.0  1140.0  1160.0  1180.0  1200.0  1220.0  1240.0  +FIX707
+FIX707 1260.0  1280.0  1300.0  1320.0  1340.0  1360.0  1380.0  1400.0  +FIX708
+FIX708 1420.0  1440.0  1460.0  1480.0  1500.0
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
$MKAEROZ 90      0.90    0       90      SAVE    CBZ60900.AIC     0       +MK1
MKAEROZ 90      0.90    0       90      ACQUIRE CBZ60900.AIC     0       +MK1
+MK1    0.025   0.075    0.15    0.3      0.5    0.75    1.0      1.2     +
+        1.6     2.0
TRIMFLT 90      0       1.0
FLUTTER 90      SYMML   90              0       0       0
FIXMDEN 90      90      0.002377   LBF/     FT                          +FIX701
+FIX701 300.0   320.0   340.0   360.0   380.0   400.0   420.0   440.0   +FIX702
+FIX702 460.0   480.0   500.0   520.0   540.0   560.0   580.0   600.0   +FIX703
+FIX703 620.0   640.0   660.0   680.0   700.0   720.0   740.0   760.0   +FIX704
+FIX704 780.0   800.0   820.0   840.0   860.0   880.0   900.0   920.0   +FIX705
+FIX705 940.0   960.0   980.0   1000.0  1020.0  1040.0  1060.0  1080.0  +FIX706
+FIX706 1100.0  1120.0  1140.0  1160.0  1180.0  1200.0  1220.0  1240.0  +FIX707
+FIX707 1260.0  1280.0  1300.0  1320.0  1340.0  1360.0  1380.0  1400.0  +FIX708
+FIX708 1420.0  1440.0  1460.0  1480.0  1500.0
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
$MKAEROZ 91      0.91    0       91      SAVE    CBZ60910.AIC     0       +MK1
MKAEROZ 91      0.91    0       91      ACQUIRE CBZ60910.AIC     0       +MK1
+MK1    0.025   0.075    0.15    0.3      0.5    0.75    1.0      1.2     +
+        1.6     2.0
TRIMFLT 91      0       1.0
FLUTTER 91      SYMML   91              0       0       0
FIXMDEN 91      91      0.002377   LBF/     FT                          +FIX701
+FIX701 300.0   320.0   340.0   360.0   380.0   400.0   420.0   440.0   +FIX702
+FIX702 460.0   480.0   500.0   520.0   540.0   560.0   580.0   600.0   +FIX703
+FIX703 620.0   640.0   660.0   680.0   700.0   720.0   740.0   760.0   +FIX704
+FIX704 780.0   800.0   820.0   840.0   860.0   880.0   900.0   920.0   +FIX705
+FIX705 940.0   960.0   980.0   1000.0  1020.0  1040.0  1060.0  1080.0  +FIX706
+FIX706 1100.0  1120.0  1140.0  1160.0  1180.0  1200.0  1220.0  1240.0  +FIX707
+FIX707 1260.0  1280.0  1300.0  1320.0  1340.0  1360.0  1380.0  1400.0  +FIX708
+FIX708 1420.0  1440.0  1460.0  1480.0  1500.0
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
$MKAEROZ 92      0.92    0       92      SAVE    CBZ60920.AIC     0       +MK1
MKAEROZ 92      0.92    0       92      ACQUIRE CBZ60920.AIC     0       +MK1
+MK1    0.025   0.075    0.15    0.3      0.5    0.75    1.0      1.2     +
+        1.6     2.0
TRIMFLT 92      0       1.0
FLUTTER 92      SYMML   92              0       0       0
FIXMDEN 92      92      0.002377   LBF/     FT                          +FIX701
+FIX701 300.0   320.0   340.0   360.0   380.0   400.0   420.0   440.0   +FIX702
+FIX702 460.0   480.0   500.0   520.0   540.0   560.0   580.0   600.0   +FIX703
+FIX703 620.0   640.0   660.0   680.0   700.0   720.0   740.0   760.0   +FIX704
+FIX704 780.0   800.0   820.0   840.0   860.0   880.0   900.0   920.0   +FIX705
+FIX705 940.0   960.0   980.0   1000.0  1020.0  1040.0  1060.0  1080.0  +FIX706
+FIX706 1100.0  1120.0  1140.0  1160.0  1180.0  1200.0  1220.0  1240.0  +FIX707
+FIX707 1260.0  1280.0  1300.0  1320.0  1340.0  1360.0  1380.0  1400.0  +FIX708
+FIX708 1420.0  1440.0  1460.0  1480.0  1500.0
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
$MKAEROZ 93      0.93    0       93      SAVE    CBZ60930.AIC     0       +MK1
MKAEROZ 93      0.93    0       93      ACQUIRE CBZ60930.AIC     0       +MK1
+MK1    0.025   0.075    0.15    0.3      0.5    0.75    1.0      1.2     +
+        1.6     2.0
TRIMFLT 93      0       1.0
FLUTTER 93      SYMML   93              0       0       0
FIXMDEN 93      93      0.002377   LBF/     FT                          +FIX701
+FIX701 300.0   320.0   340.0   360.0   380.0   400.0   420.0   440.0   +FIX702
+FIX702 460.0   480.0   500.0   520.0   540.0   560.0   580.0   600.0   +FIX703
+FIX703 620.0   640.0   660.0   680.0   700.0   720.0   740.0   760.0   +FIX704
+FIX704 780.0   800.0   820.0   840.0   860.0   880.0   900.0   920.0   +FIX705
+FIX705 940.0   960.0   980.0   1000.0  1020.0  1040.0  1060.0  1080.0  +FIX706
+FIX706 1100.0  1120.0  1140.0  1160.0  1180.0  1200.0  1220.0  1240.0  +FIX707
+FIX707 1260.0  1280.0  1300.0  1320.0  1340.0  1360.0  1380.0  1400.0  +FIX708
+FIX708 1420.0  1440.0  1460.0  1480.0  1500.0
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
$MKAEROZ 95      0.95    0       95      SAVE    CBZ60950.AIC     0       +MK1
MKAEROZ 95      0.95    0       95      ACQUIRE CBZ60950.AIC     0       +MK1
+MK1    0.025   0.075    0.15    0.3      0.5    0.75    1.0      1.2     +
+        1.6     2.0
```

```
TRIMFLT 95      0       1.0
FLUTTER 95      SYMML   95              0       0       0
FIXMDEN 95      95      0.002377   LBF/    FT                              +FIX701
+FIX701 300.0   320.0   340.0   360.0   380.0   400.0   420.0   440.0   +FIX702
+FIX702 460.0   480.0   500.0   520.0   540.0   560.0   580.0   600.0   +FIX703
+FIX703 620.0   640.0   660.0   680.0   700.0   720.0   740.0   760.0   +FIX704
+FIX704 780.0   800.0   820.0   840.0   860.0   880.0   900.0   920.0   +FIX705
+FIX705 940.0   960.0   980.0   1000.0  1020.0  1040.0  1060.0  1080.0  +FIX706
+FIX706 1100.0  1120.0  1140.0  1160.0  1180.0  1200.0  1220.0  1240.0  +FIX707
+FIX707 1260.0  1280.0  1300.0  1320.0  1340.0  1360.0  1380.0  1400.0  +FIX708
+FIX708 1420.0  1440.0  1460.0  1480.0  1500.0

$  baseaero.inp
$  AERODYNAMIC PANELS AND SPLINE
$
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
CORD2R        11           0.000   0.000   0.000   0.000   0.000   1.000+CR11
+CR11      0.000  -1.000   1.000
$
$ MAIN WING
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
ACOORD        50     0.0     0.0     0.0     0.0     0.0     0.0
$
$  Aerodynamic Model
$.......2.......3.......4.......5.......6.......7.......8.......9.......10.....$
$CAERO7  100001  GOLAND          6       20                        0       +ARO101
CAERO7  100001  GOLAND          21      39                      100001  +ARO101
+ARO101 0.0     0.0     0.0     6.0                                     +ARO102
+ARO102 0.0     20.0    0.0     6.0
$.......2.......3.......4.......5.......6.......7.......8.......9.......10.....$
PAFOIL7 100001  100002  100003  100004          100003  100004
AEFACT  100002  0.00    5.00    10.00   15.00   20.00   25.00   30.00    +AEF201
+AEF201 35.00   40.00   45.00   50.00   55.00   60.00   65.00   70.00    +AEF202
+AEF202 75.00   80.00   85.00   90.00   95.00   100.00
AEFACT  100003  0.0000  0.0038  0.0072  0.0102  0.0128  0.0150  0.0168  +AEF301
+AEF301 0.0182  0.0192  0.0198  0.0200  0.0198  0.0192  0.0182  0.0168  +AEF302
+AEF302 0.0150  0.0128  0.0102  0.0072  0.0038  0.0000
AEFACT  100004  0.00    0.00    0.00    0.00    0.00    0.00    0.00    +AEF401
+AEF401 0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    +AEF402
+AEF402 0.00    0.00    0.00    0.00    0.00    0.00
AEROZ           YES      NO                      6.0     20.0    120.0  +AERO01
+AERO01 1.5     0.0     0.0
$  Spline
$.......2.......3.......4.......5.......6.......7.......8.......9.......10.....$
SPLINE1 100001                  100001  101     0.0
PANLST3 100001  GOLAND
SET1    101     10000   10001   10002   10100   10101   10102   10200   +ET101
+ET101  10201   10202   10300   10301   10302   10400   10401   10402   +ET101A
+ET101A 10500   10501   10502   10600   10601   10602   10700   10701   +ET101B
+ET101B 10702   10800   10801   10802   10900   10901   10902   11000   +ET101C
+ET101C 11001   11002
$ STATEMENT TO CHECK COORDINATE SYSTEM OF CFD MESH, AERODYNAMIC MODEL AND
$ FINITE ELEMENT MODEL.
$.......2.......3.......4.......5.......6.......7.......8.......9.......10.....$
PLTAERO 100     YES             TECPLOT AEROSTRUC_CS.PLTYES     YES
```

APPENDIX F: Example Input File for ZAERO® ZTRAN, Euler CFD Model

```
$ ... Executive Control
ASSIGN FEM=basecw0000.f06, PRINT=0, FORM=MSC, BOUND=SYM
ASSIGN MATRIX =basecw0000.mgh, FORM=FORMAT,   MNAME=SMGH, PRINT=0
MEMORY 850MB
$SOL -2
CEND
$ ... Case Control
TITLE   = AEROELASTIC ANALYSIS OF Goland Wing
ECHO    = SORT
    SUBCASE = 70
      SUBTITLE =  LINEAR FLUTTER ANALYSIS
      LABEL    =  MACH NUMBER =  0.70, NON MATCHED-POINT FLUTTER ANALYSIS
      FLUTTER  = 70
    SUBCASE = 80
      SUBTITLE =  LINEAR FLUTTER ANALYSIS
      LABEL    =  MACH NUMBER =  0.80, NON MATCHED-POINT FLUTTER ANALYSIS
      FLUTTER  = 80
     SUBCASE = 85
      SUBTITLE =  LINEAR FLUTTER ANALYSIS
      LABEL    =  MACH NUMBER =  0.85, NON MATCHED-POINT FLUTTER ANALYSIS
      FLUTTER  = 85
    SUBCASE = 88
      SUBTITLE =  LINEAR FLUTTER ANALYSIS
      LABEL    =  MACH NUMBER =  0.88, NON MATCHED-POINT FLUTTER ANALYSIS
      FLUTTER  = 88
     SUBCASE = 90
      SUBTITLE =  LINEAR FLUTTER ANALYSIS
      LABEL    =  MACH NUMBER =  0.90, NON MATCHED-POINT FLUTTER ANALYSIS
      FLUTTER  = 90
    SUBCASE = 91
      SUBTITLE =  LINEAR FLUTTER ANALYSIS
      LABEL    =  MACH NUMBER =  0.91, NON MATCHED-POINT FLUTTER ANALYSIS
      FLUTTER  = 91
    SUBCASE = 92
      SUBTITLE =  LINEAR FLUTTER ANALYSIS
      LABEL    =  MACH NUMBER =  0.92, NON MATCHED-POINT FLUTTER ANALYSIS
      FLUTTER  = 92
    SUBCASE = 93
      SUBTITLE =  LINEAR FLUTTER ANALYSIS
      LABEL    =  MACH NUMBER =  0.93, NON MATCHED-POINT FLUTTER ANALYSIS
      FLUTTER  = 93
    SUBCASE = 95
      SUBTITLE =  LINEAR FLUTTER ANALYSIS
      LABEL    =  MACH NUMBER =  0.95, NON MATCHED-POINT FLUTTER ANALYSIS
      FLUTTER  = 95
$ ... Bulk Data Deck
BEGIN BULK
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
PLTVG       88   88               EQUV  TABLE   CBTE0880000.dat
PLTVG        70      70            EQUV  TABLE  CBTE0700000.dat
PLTVG        80      80            EQUV  TABLE  CBTE0800000.dat
PLTVG        85      85            EQUV  TABLE  CBTE0850000.dat
PLTVG        90      90            EQUV  TABLE  CBTE0900000.dat
PLTVG        91      91            EQUV  TABLE  CBTE0910000.dat
PLTVG        92      92            EQUV  TABLE  CBTE0920000.dat
PLTVG        93      93            EQUV  TABLE  CBTE0930000.dat
PLTVG        95      95            EQUV  TABLE  CBTE0950000.dat
include 'baseaero.inp'
include 'alt_mkz_cw_eu.inp'
ENDDATA

$'baseaero.inp'
$  AERODYNAMIC PANELS AND SPLINE
$
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
CORD2R        11           0.000   0.000   0.000   0.000   0.000   1.000+CR11
+CR11      0.000  -1.000   1.000
$
$ MAIN WING
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
ACOORD        50     0.0     0.0     0.0     0.0     0.0     0.0
```

```
$
$  Aerodynamic Model
$.......2.......3.......4.......5.......6.......7.......8.......9.......10.....$
CAERO7  100001  GOLAND          21      39                      100001  +ARO101
+ARO101 0.0     0.0     0.0     6.0      0       0                      +ARO102
+ARO102 0.0     20.0    0.0     6.0      0       0
CELLWNG 10001   100001   1       3               20001
        7       6.0      6.0     0.      0.      COS      4       6
        7       6.0      6.0     0.      0.      COS      4       6
        2       .6       .6              2       .6       .6
CELLWNG 20001   100001   3       5       10001   30001
        7       6.0      6.0     0.      0.      COS      4       6
        7       6.0      6.0     0.      0.      COS      4       6
        2       .6       .6              2       .6       .6
CELLWNG 30001   100001   5       7       20001   40001
        7       6.0      6.0     0.      0.      COS      4       6
        7       6.0      6.0     0.      0.      COS      4       6
        2       .6       .6              2       .6       .6
CELLWNG 40001   100001   7       9       30001   50001
        7       6.0      6.0     0.      0.      COS      4       6
        7       6.0      6.0     0.      0.      COS      4       6
        2       .6       .6              2       .6       .6
CELLWNG 50001   100001   9       11      40001   60001
        7       6.0      6.0     0.      0.      COS      4       6
        7       6.0      6.0     0.      0.      COS      4       6
        2       .6       .6              2       .6       .6
CELLWNG 60001   100001   11      13      50001   70001
        7       6.0      6.0     0.      0.      COS      4       6
        7       6.0      6.0     0.      0.      COS      4       6
        2       .6      .6              2       .6       .6
CELLWNG 70001   100001   13     15       60001   80001
        7       6.0      6.0     0.      0.      COS      4       6
        7       6.0      6.0     0.      0.      COS      4       6
        2       .6       .6              2       .6       .6
CELLWNG 80001   100001   15      17      70001   90001
        7       6.0      6.0     0.      0.      COS      4       6
        7       6.0      6.0     0.      0.      COS      4       6
        2       .6       .6              2       .6       .6
CELLWNG 90001   100001   17      19      80001   100001
        7       6.0      6.0     0.      0.      COS      4       6
        7       6.0      6.0     0.      0.      COS      4       6
        2       .6       .6              2       .6       .6
CELLWNG 100001  100001   19      21      90001
        7       6.0      6.0     0.      0.      COS      4       6
        7       6.0      6.0     0.      0.      COS      4       6
        2       .6       .6              2       .6       .6
$.......2.......3.......4.......5.......6.......7.......8.......9.......10.....$
PAFOIL7 100001  100002  100003  100004          100003  100004
AEFACT  100002  0.00    5.00    10.00   15.00   20.00   25.00   30.00    +AEF201
+AEF201 35.00   40.00   45.00   50.00   55.00   60.00   65.00   70.00    +AEF202
+AEF202 75.00   80.00   85.00   90.00   95.00   100.00
AEFACT  100003  0.0000  0.38    0.72    1.02    1.28    1.50    1.68    +AEF301
+AEF301 1.82    1.92    1.98    2.00    1.98    1.92    1.82    1.68    +AEF302
+AEF302 1.50    1.28    1.02    0.72    0.38    0.0000
AEFACT  100004  0.00    0.00    0.00    0.00    0.00    0.00    0.00    +AEF401
+AEF401 0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    +AEF402
+AEF402 0.00    0.00    0.00    0.00    0.00    0.00
AEROZ   0       YES      NO                      6.0     20.0    120.0  +AERO01
+AERO01 1.5     0.0     0.0
$  Spline
SPLINE1 100001                  100001  101
PANLST3 100001  GOLAND
$.......2.......3.......4.......5.......6.......7.......8.......9.......10.....$
SET1    101     10000   10001   10002   10100   10101   10102      10200+ET101
+ET101  10201   10202   10300   10301   10302   10400   10401      10402+ET101A
+ET101A 10500   10501   10502   10600   10601   10602   10700      10701+ET101B
+ET101B 10702   10800   10801   10802   10900   10901   10902      11000+ET101C
+ET101C 11001   11002
$ STATEMENT TO CHECK COORDINATE SYSTEM OF CFD MESH, AERODYNAMIC MODEL AND
$ FINITE ELEMENT MODEL.
$.......2.......3.......4.......5.......6.......7.......8.......9.......10.....$
PLTAERO 100     YES             TECPLOT AEROSTRUC_CS.PLTYES     YES
```

```
$ 'alt_mkz_cw_eu.inp'
$ case 70 Mach 0.70
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
$       IDMK    MACH    METHOD  IDFLT   SAVE    <--FILENAME-->  PRINT   $
$       FREQ1   FREQ2   ETC
$MKAEROZ 70       0.70    -3       70    SAVE    CBTE0700r2.AIC     0       +MK1
MKAEROZ 70        0.70    -3       70   ACQUIRE CBTE0700r2.AIC    0       +MK1
+MK1    0.025   0.075    0.15    0.3      0.5    0.75    1.0      1.2     +
+        1.6     2.0
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
TRIMFLT   70       70       1.0
INPCFD  70      101     10       P3D     goland.grid    goland_0.70.sol
FLUTTER 70      SYM     70              0       0       0
FIXMDEN 70      70      0.002377   LBF/     FT                          +FIX701
+FIX701 300.0   320.0   340.0   360.0   380.0   400.0   420.0   440.0   +FIX702
+FIX702 460.0   480.0   500.0   520.0   540.0   560.0   580.0   600.0   +FIX703
+FIX703 620.0   640.0   660.0   680.0   700.0   720.0   740.0   760.0   +FIX704
+FIX704 780.0   800.0   820.0   840.0   860.0   880.0   900.0   920.0   +FIX705
+FIX705 940.0   960.0   980.0   1000.0  1020.0  1040.0  1060.0  1080.0  +FIX706
+FIX706 1100.0  1120.0  1140.0  1160.0  1180.0  1200.0  1220.0  1240.0  +FIX707
+FIX707 1260.0  1280.0  1300.0  1320.0  1340.0  1360.0  1380.0  1400.0  +FIX708
+FIX708 1420.0  1440.0  1460.0  1480.0  1500.0
$ case 80 Mach 0.80
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
$MKAEROZ 80        0.80    -3      80      SAVE   CBTE0800r2.AIC     0      +MK1
MKAEROZ 80      0.80    -3       80     ACQUIRE  CBTE0800r2.AIC    0       +MK1
+MK1    0.025   0.075    0.15    0.3      0.5    0.75    1.0      1.2     +
+        1.6     2.0
TRIMFLT 80       80       1.0
INPCFD  80      101     10       P3D     goland.grid    goland_0.80.sol
FLUTTER 80      SYM     80              0       0       0
FIXMDEN 80      80      0.002377  LBF/     FT                           +FIX701
+FIX701 300.0   320.0   340.0   360.0   380.0   400.0   420.0   440.0   +FIX702
+FIX702 460.0   480.0   500.0   520.0   540.0   560.0   580.0   600.0   +FIX703
+FIX703 620.0   640.0   660.0   680.0   700.0   720.0   740.0   760.0   +FIX704
+FIX704 780.0   800.0   820.0   840.0   860.0   880.0   900.0   920.0   +FIX705
+FIX705 940.0   960.0   980.0   1000.0  1020.0  1040.0  1060.0  1080.0  +FIX706
+FIX706 1100.0  1120.0  1140.0  1160.0  1180.0  1200.0  1220.0  1240.0  +FIX707
+FIX707 1260.0  1280.0  1300.0  1320.0  1340.0  1360.0  1380.0  1400.0  +FIX708
+FIX708 1420.0  1440.0  1460.0  1480.0  1500.0
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
$MKAEROZ 85        0.85    -3      85      SAVE   CBTE0850r2.AIC     0      +MK1
MKAEROZ 85      0.85     -3      85     ACQUIRE CBTE0850r2.AIC   0       +MK1
+MK1    0.025   0.075    0.15    0.3      0.5    0.75    1.0      1.2     +
+        1.6     2.0
TRIMFLT 85      85       1.0
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
INPCFD  85      101     10       P3D     goland.grid    goland_0.85.sol
FLUTTER 85      SYM     85              0       0       0
FIXMDEN 85      85      0.002377  LBF/     FT                           +FIX701
+FIX701 300.0   320.0   340.0   360.0   380.0   400.0   420.0   440.0   +FIX702
+FIX702 460.0   480.0   500.0   520.0   540.0   560.0   580.0   600.0   +FIX703
+FIX703 620.0   640.0   660.0   680.0   700.0   720.0   740.0   760.0   +FIX704
+FIX704 780.0   800.0   820.0   840.0   860.0   880.0   900.0   920.0   +FIX705
+FIX705 940.0   960.0   980.0   1000.0  1020.0  1040.0  1060.0  1080.0  +FIX706
+FIX706 1100.0  1120.0  1140.0  1160.0  1180.0  1200.0  1220.0  1240.0  +FIX707
+FIX707 1260.0  1280.0  1300.0  1320.0  1340.0  1360.0  1380.0  1400.0  +FIX708
+FIX708 1420.0  1440.0  1460.0  1480.0  1500.0
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
$MKAEROZ 88      0.88    -3       88      SAVE    CBTE0880r2.AIC     0      +MK1
MKAEROZ 88      0.88    -3      88      ACQUIRE CBTE0880r2.AIC    0       +MK1
+MK1    0.025   0.075    0.15    0.3      0.5    0.75    1.0      1.2     +
+        1.6     2.0
TRIMFLT 88      88       1.0
INPCFD  88      101     10       P3D     goland.grid    goland_0.88.sol
FLUTTER 88      SYM     88              0       0       0
FIXMDEN 88      88      0.002377  LBF/      FT                          +FIX701
+FIX701 300.0   320.0   340.0   360.0   380.0   400.0   420.0   440.0   +FIX702
+FIX702 460.0   480.0   500.0   520.0   540.0   560.0   580.0   600.0   +FIX703
+FIX703 620.0   640.0   660.0   680.0   700.0   720.0   740.0   760.0   +FIX704
+FIX704 780.0   800.0   820.0   840.0   860.0   880.0   900.0   920.0   +FIX705
+FIX705 940.0   960.0   980.0   1000.0  1020.0  1040.0  1060.0  1080.0  +FIX706
```

```
+FIX706 1100.0  1120.0  1140.0  1160.0  1180.0  1200.0  1220.0  1240.0  +FIX707
+FIX707 1260.0  1280.0  1300.0  1320.0  1340.0  1360.0  1380.0  1400.0  +FIX708
+FIX708 1420.0  1440.0  1460.0  1480.0  1500.0
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
$MKAEROZ 90      0.90    -3       90      SAVE    CBTE0900r2.AIC     0      +MK1
MKAEROZ 90      0.90    -3       90     ACQUIRE CBTE0900r2.AIC     0      +MK1
+MK1    0.025   0.075    0.15    0.3      0.5    0.75    1.0      1.2     +
+        1.6     2.0
TRIMFLT 90      90       1.0
INPCFD  90      101     10       P3D     goland.grid    goland_0.90.sol
FLUTTER 90      SYM     90              0       0       0
FIXMDEN 90      90      0.002377  LBF/     FT                           +FIX701
+FIX701 300.0   320.0   340.0   360.0   380.0   400.0   420.0   440.0   +FIX702
+FIX702 460.0   480.0   500.0   520.0   540.0   560.0   580.0   600.0   +FIX703
+FIX703 620.0   640.0   660.0   680.0   700.0   720.0   740.0   760.0   +FIX704
+FIX704 780.0   800.0   820.0   840.0   860.0   880.0   900.0   920.0   +FIX705
+FIX705 940.0   960.0   980.0   1000.0  1020.0  1040.0  1060.0  1080.0  +FIX706
+FIX706 1100.0  1120.0  1140.0  1160.0  1180.0  1200.0  1220.0  1240.0  +FIX707
+FIX707 1260.0  1280.0  1300.0  1320.0  1340.0  1360.0  1380.0  1400.0  +FIX708
+FIX708 1420.0  1440.0  1460.0  1480.0  1500.0
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
$MKAEROZ 91      0.91    -3       91      SAVE    CBTE0910r2.AIC     0      +MK1
MKAEROZ 91      0.91    -3       91     ACQUIRE CBTE0910r2.AIC    0       +MK1
+MK1    0.025   0.075    0.15    0.3      0.5    0.75    1.0      1.2     +
+        1.6     2.0
TRIMFLT 91      91       1.0
INPCFD  91      101     10       P3D     goland.grid    goland_0.90.sol
FLUTTER 91      SYM     91              0       0       0
FIXMDEN 91      91      0.002377  LBF/     FT                           +FIX701
+FIX701 300.0   320.0   340.0   360.0   380.0   400.0   420.0   440.0   +FIX702
+FIX702 460.0   480.0   500.0   520.0   540.0   560.0   580.0   600.0   +FIX703
+FIX703 620.0   640.0   660.0   680.0   700.0   720.0   740.0   760.0   +FIX704
+FIX704 780.0   800.0   820.0   840.0   860.0   880.0   900.0   920.0   +FIX705
+FIX705 940.0   960.0   980.0   1000.0  1020.0  1040.0  1060.0  1080.0  +FIX706
+FIX706 1100.0  1120.0  1140.0  1160.0  1180.0  1200.0  1220.0  1240.0  +FIX707
+FIX707 1260.0  1280.0  1300.0  1320.0  1340.0  1360.0  1380.0  1400.0  +FIX708
+FIX708 1420.0  1440.0  1460.0  1480.0  1500.0
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
$MKAEROZ 92      0.92    -3       92      SAVE    CBTE0920r2.AIC     0      +MK1
MKAEROZ 92      0.92    -3      92      ACQUIRE CBTE0920r2.AIC     0       +MK1
+MK1    0.025   0.075    0.15    0.3      0.5    0.75    1.0      1.2     +
+        1.6     2.0
TRIMFLT 92      92       1.0
INPCFD  92      101     10       P3D     goland.grid    goland_0.92.sol
FLUTTER 92      SYM     92              0       0       0
FIXMDEN 92      92      0.002377  LBF/     FT                           +FIX701
+FIX701 300.0   320.0   340.0   360.0   380.0   400.0   420.0   440.0   +FIX702
+FIX702 460.0   480.0   500.0   520.0   540.0   560.0   580.0   600.0   +FIX703
+FIX703 620.0   640.0   660.0   680.0   700.0   720.0   740.0   760.0   +FIX704
+FIX704 780.0   800.0   820.0   840.0   860.0   880.0   900.0   920.0   +FIX705
+FIX705 940.0   960.0   980.0   1000.0  1020.0  1040.0  1060.0  1080.0  +FIX706
+FIX706 1100.0  1120.0  1140.0  1160.0  1180.0  1200.0  1220.0  1240.0  +FIX707
+FIX707 1260.0  1280.0  1300.0  1320.0  1340.0  1360.0  1380.0  1400.0  +FIX708
+FIX708 1420.0  1440.0  1460.0  1480.0  1500.0
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
$MKAEROZ 93      0.93    -3       93      SAVE    CBTE0930r2.AIC     0      +MK1
MKAEROZ 93      0.93    -3      93      ACQUIRE  CBTE0930r2.AIC     0      +MK1
+MK1    0.025   0.075    0.15    0.3      0.5    0.75    1.0      1.2     +
+        1.6     2.0
TRIMFLT 93      93       1.0
INPCFD  93      101     10       P3D     goland.grid    goland_0.93.sol
FLUTTER 93      SYM     93              0       0       0
FIXMDEN 93      93      0.002377  LBF/     FT                           +FIX701
+FIX701 300.0   320.0   340.0   360.0   380.0   400.0   420.0   440.0   +FIX702
+FIX702 460.0   480.0   500.0   520.0   540.0   560.0   580.0   600.0   +FIX703
+FIX703 620.0   640.0   660.0   680.0   700.0   720.0   740.0   760.0   +FIX704
+FIX704 780.0   800.0   820.0   840.0   860.0   880.0   900.0   920.0   +FIX705
+FIX705 940.0   960.0   980.0   1000.0  1020.0  1040.0  1060.0  1080.0  +FIX706
+FIX706 1100.0  1120.0  1140.0  1160.0  1180.0  1200.0  1220.0  1240.0  +FIX707
+FIX707 1260.0  1280.0  1300.0  1320.0  1340.0  1360.0  1380.0  1400.0  +FIX708
+FIX708 1420.0  1440.0  1460.0  1480.0  1500.0
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
$MKAEROZ 95      0.95    -3       95      SAVE    CBTE0950r2.AIC     0      +MK1
```

```
MKAEROZ 95      0.95    -3      95      ACQUIRE  CBTE0950r2.AIC     0       +MK1
+MK1    0.025   0.075    0.15    0.3      0.5    0.75    1.0      1.2     +
+        1.6     2.0
TRIMFLT 95      95       1.0
INPCFD  95      101     10       P3D     goland.grid    goland_0.95.sol
FLUTTER 95      SYM     95              0       0       0
FIXMDEN 95      95      0.002377  LBF/      FT                              +FIX701
+FIX701 300.0   320.0   340.0   360.0   380.0   400.0   420.0   440.0   +FIX702
+FIX702 460.0   480.0   500.0   520.0   540.0   560.0   580.0   600.0   +FIX703
+FIX703 620.0   640.0   660.0   680.0   700.0   720.0   740.0   760.0   +FIX704
+FIX704 780.0   800.0   820.0   840.0   860.0   880.0   900.0   920.0   +FIX705
+FIX705 940.0   960.0   980.0   1000.0  1020.0  1040.0  1060.0  1080.0  +FIX706
+FIX706 1100.0  1120.0  1140.0  1160.0  1180.0  1200.0  1220.0  1240.0  +FIX707
+FIX707 1260.0  1280.0  1300.0  1320.0  1340.0  1360.0  1380.0  1400.0  +FIX708
+FIX708 1420.0  1440.0  1460.0  1480.0  1500.0
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
OMITCFD 10              TECPLOT SURFACE.PLT     SURFACE.SOL
         1       41      121     1       42      51      51
         2       41      121     1       42      1       1
CORD2R  101             0.0     0.0     0.0     0.0     -1.     0.0
        1.0     0.0     0.0
```

APPENDIX G: Example Input File for ZAERO® ZTRAN, Navier Stokes CFD Model

```
$ ... Executive Control
ASSIGN FEM=basecw0000.f06, PRINT=0, FORM=MSC, BOUND=SYM
ASSIGN MATRIX =basecw0000.mgh, FORM=FORMAT,   MNAME=SMGH, PRINT=0
MEMORY 850MB
$SOL -2
CEND
$ ... Case Control
TITLE   = AEROELASTIC ANALYSIS OF Goland Wing
ECHO    = SORT
    SUBCASE = 70
      SUBTITLE =  LINEAR FLUTTER ANALYSIS
      LABEL    =  MACH NUMBER =  0.70, NON MATCHED-POINT FLUTTER ANALYSIS
      FLUTTER  = 70
    SUBCASE = 80
      SUBTITLE =  LINEAR FLUTTER ANALYSIS
      LABEL    =  MACH NUMBER =  0.80, NON MATCHED-POINT FLUTTER ANALYSIS
      FLUTTER  = 80
    SUBCASE = 825
      SUBTITLE =  LINEAR FLUTTER ANALYSIS
      LABEL    =  MACH NUMBER =  0.825, NON MATCHED-POINT FLUTTER ANALYSIS
      FLUTTER  = 825
     SUBCASE = 85
      SUBTITLE =  LINEAR FLUTTER ANALYSIS
      LABEL    =  MACH NUMBER =  0.85, NON MATCHED-POINT FLUTTER ANALYSIS
      FLUTTER  = 85
    SUBCASE = 88
      SUBTITLE =  LINEAR FLUTTER ANALYSIS
      LABEL    =  MACH NUMBER =  0.88, NON MATCHED-POINT FLUTTER ANALYSIS
      FLUTTER  = 88
     SUBCASE = 90
      SUBTITLE =  LINEAR FLUTTER ANALYSIS
      LABEL    =  MACH NUMBER =  0.90, NON MATCHED-POINT FLUTTER ANALYSIS
      FLUTTER  = 90
    SUBCASE = 91
      SUBTITLE =  LINEAR FLUTTER ANALYSIS
      LABEL    =  MACH NUMBER =  0.91, NON MATCHED-POINT FLUTTER ANALYSIS
      FLUTTER  = 91
    SUBCASE = 92
      SUBTITLE =  LINEAR FLUTTER ANALYSIS
      LABEL    =  MACH NUMBER =  0.92, NON MATCHED-POINT FLUTTER ANALYSIS
      FLUTTER  = 92
    SUBCASE = 93
      SUBTITLE =  LINEAR FLUTTER ANALYSIS
      LABEL    =  MACH NUMBER =  0.93, NON MATCHED-POINT FLUTTER ANALYSIS
      FLUTTER  = 93
    SUBCASE = 95
      SUBTITLE =  LINEAR FLUTTER ANALYSIS
      LABEL    =  MACH NUMBER =  0.95, NON MATCHED-POINT FLUTTER ANALYSIS
      FLUTTER  = 95
$ ... Bulk Data Deck
BEGIN BULK
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
PLTVG       70      70          EQUV  TABLE  CBTN0700000.dat
PLTVG       80      80          EQUV  TABLE  CBTN0800000.dat
PLTVG      825     825          EQUV  TABLE  CBTN8250000.dat
PLTVG       85      85          EQUV  TABLE  CBTN0850000.dat
PLTVG       88      88          EQUV  TABLE  CBTN0880000.dat
PLTVG       90      90          EQUV  TABLE  CBTN0900000.dat
PLTVG       91      91          EQUV  TABLE  CBTN0910000.dat
PLTVG       92      92          EQUV  TABLE  CBTN0920000.dat
PLTVG       93      93          EQUV  TABLE  CBTN0930000.dat
PLTVG       95      95          EQUV  TABLE  CBTN0950000.dat
include 'baseaero.inp'
include 'alt_mkz_cw_ns.inp'
ENDDATA

$ 'baseaero.inp'
$  AERODYNAMIC PANELS AND SPLINE
$
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
CORD2R       11          0.000   0.000   0.000   0.000   0.000   1.000+CR11
```

```
+CR11      0.000  -1.000   1.000
$
$ MAIN WING
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
ACOORD        50     0.0     0.0     0.0     0.0     0.0     0.0
$
$  Aerodynamic Model
$.......2.......3.......4.......5.......6.......7.......8.......9.......10.....$
CAERO7  100001  GOLAND          21      39                      100001  +ARO101
+ARO101 0.0     0.0     0.0     6.0      0       0                      +ARO102
+ARO102 0.0     20.0    0.0     6.0      0       0
CELLWNG 10001   100001   1       3               20001
        7       6.0      6.0     0.      0.      COS      4       6
        7       6.0      6.0     0.      0.      COS      4       6
        2       .6       .6              2       .6       .6
CELLWNG 20001   100001   3       5       10001   30001
        7       6.0      6.0     0.      0.      COS      4       6
        7       6.0      6.0     0.      0.      COS      4       6
        2       .6       .6              2       .6       .6
CELLWNG 30001   100001   5       7       20001   40001
        7       6.0      6.0     0.      0.      COS      4       6
        7       6.0      6.0     0.      0.      COS      4       6
        2       .6       .6              2       .6       .6
CELLWNG 40001   100001   7       9       30001   50001
        7       6.0      6.0     0.      0.      COS      4       6
        7       6.0      6.0     0.      0.      COS      4       6
        2       .6       .6              2       .6       .6
CELLWNG 50001   100001   9       11      40001   60001
        7       6.0      6.0     0.      0.      COS      4       6
        7       6.0      6.0     0.      0.      COS      4       6
        2       .6       .6              2       .6       .6
CELLWNG 60001   100001   11      13      50001   70001
        7       6.0      6.0     0.      0.      COS      4       6
        7       6.0      6.0     0.      0.      COS      4       6
        2       .6      .6              2       .6       .6
CELLWNG 70001   100001   13     15       60001   80001
        7       6.0      6.0     0.      0.      COS      4       6
        7       6.0      6.0     0.      0.      COS      4       6
        2       .6       .6              2       .6       .6
CELLWNG 80001   100001   15      17      70001   90001
        7       6.0      6.0     0.      0.      COS      4       6
        7       6.0      6.0     0.      0.      COS      4       6
        2       .6       .6              2       .6       .6
CELLWNG 90001   100001   17      19      80001   100001
        7       6.0      6.0     0.      0.      COS      4       6
        7       6.0      6.0     0.      0.      COS      4       6
        2       .6       .6              2       .6       .6
CELLWNG 100001  100001   19      21      90001
        7       6.0      6.0     0.      0.      COS      4       6
        7       6.0      6.0     0.      0.      COS      4       6
        2       .6       .6              2       .6       .6
$.......2.......3.......4.......5.......6.......7.......8.......9.......10.....$
PAFOIL7 100001  100002  100003  100004          100003  100004
AEFACT  100002  0.00    5.00    10.00   15.00   20.00   25.00   30.00    +AEF201
+AEF201 35.00   40.00   45.00   50.00   55.00   60.00   65.00   70.00    +AEF202
+AEF202 75.00   80.00   85.00   90.00   95.00   100.00
AEFACT  100003  0.0000  0.38    0.72    1.02    1.28    1.50    1.68    +AEF301
+AEF301 1.82    1.92    1.98    2.00    1.98    1.92    1.82    1.68    +AEF302
+AEF302 1.50    1.28    1.02    0.72    0.38    0.0000
AEFACT  100004  0.00    0.00    0.00    0.00    0.00    0.00    0.00    +AEF401
+AEF401 0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00    +AEF402
+AEF402 0.00    0.00    0.00    0.00    0.00    0.00
AEROZ   0       YES      NO                      6.0     20.0    120.0  +AERO01
+AERO01 1.5     0.0     0.0
$  Spline
SPLINE1 100001                  100001  101
PANLST3 100001  GOLAND
$.......2.......3.......4.......5.......6.......7.......8.......9.......10.....$
SET1    101     10000   10001   10002   10100   10101   10102      10200+ET101
+ET101  10201   10202   10300   10301   10302   10400   10401      10402+ET101A
+ET101A 10500   10501   10502   10600   10601   10602   10700      10701+ET101B
+ET101B 10702   10800   10801   10802   10900   10901   10902      11000+ET101C
+ET101C 11001   11002
```

```
$ STATEMENT TO CHECK COORDINATE SYSTEM OF CFD MESH, AERODYNAMIC MODEL AND
$ FINITE ELEMENT MODEL.
$.......2.......3.......4.......5.......6.......7.......8.......9.......10.....$
PLTAERO 100     YES             TECPLOT AEROSTRUC_CS.PLTYES     YES
$

$'alt_mkz_cw_ns.inp'
$ case 70 Mach 0.70
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
$       IDMK    MACH    METHOD  IDFLT   SAVE    <--FILENAME-->  PRINT   $
$       FREQ1   FREQ2   ETC
$MKAEROZ 70      0.70    -3       70      SAVE    CBTN0700r2.AIC     0      +MK1
MKAEROZ 70       0.70    -3       70    ACQUIRE CBTN0700r2.AIC     0      +MK1
+MK1    0.025   0.075    0.15    0.3      0.5    0.75    1.0      1.2     +
+        1.6     2.0
TRIMFLT 70      70      1.0
INPCFD  70      101     10      PLOT3D   goland_NS.grid     $70
EXTFILE  70     goland_0.7_ns.sol
FLUTTER 70      SYM     70              0       0       0
FIXMDEN 70      70      0.002377   LBF/     FT                          +FIX701
+FIX701 300.0   320.0   340.0   360.0   380.0   400.0   420.0   440.0   +FIX702
+FIX702 460.0   480.0   500.0   520.0   540.0   560.0   580.0   600.0   +FIX703
+FIX703 620.0   640.0   660.0   680.0   700.0   720.0   740.0   760.0   +FIX704
+FIX704 780.0   800.0   820.0   840.0   860.0   880.0   900.0   920.0   +FIX705
+FIX705 940.0   960.0   980.0   1000.0  1020.0  1040.0  1060.0  1080.0  +FIX706
+FIX706 1100.0  1120.0  1140.0  1160.0  1180.0  1200.0  1220.0  1240.0  +FIX707
+FIX707 1260.0  1280.0  1300.0  1320.0  1340.0  1360.0  1380.0  1400.0  +FIX708
+FIX708 1420.0  1440.0  1460.0  1480.0  1500.0
$ case 80 Mach 0.80
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
$MKAEROZ 80      0.80    -3       80      SAVE    CBTN0800r2.AIC     0      +MK1
MKAEROZ 80      0.80    -3       80     ACQUIRE CBTN0800r2.AIC     0      +MK1
+MK1    0.025   0.075    0.15    0.3      0.5    0.75    1.0      1.2     +
+        1.6     2.0
TRIMFLT 80      80      1.0
INPCFD  80      101     10      PLOT3D   goland_NS.grid     $80
EXTFILE 80      goland_0.8_ns.sol
FLUTTER 80      SYM     80              0       0       0
FIXMDEN 80      80      0.002377  LBF/     FT                           +FIX701
+FIX701 300.0   320.0   340.0   360.0   380.0   400.0   420.0   440.0   +FIX702
+FIX702 460.0   480.0   500.0   520.0   540.0   560.0   580.0   600.0   +FIX703
+FIX703 620.0   640.0   660.0   680.0   700.0   720.0   740.0   760.0   +FIX704
+FIX704 780.0   800.0   820.0   840.0   860.0   880.0   900.0   920.0   +FIX705
+FIX705 940.0   960.0   980.0   1000.0  1020.0  1040.0  1060.0  1080.0  +FIX706
+FIX706 1100.0  1120.0  1140.0  1160.0  1180.0  1200.0  1220.0  1240.0  +FIX707
+FIX707 1260.0  1280.0  1300.0  1320.0  1340.0  1360.0  1380.0  1400.0  +FIX708
+FIX708 1420.0  1440.0  1460.0  1480.0  1500.0
$ case 825 Mach 0.825
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
$MKAEROZ  825     0.825   -3      825     SAVE    CBTN0825r2.AIC   0       +MK1
MKAEROZ 825     0.825   -3       825    ACQUIRE CBTN0825r2.AIC     0      +MK1
+MK1    0.025   0.075    0.15    0.3      0.5    0.75    1.0      1.2     +
+        1.6     2.0
TRIMFLT 825     825     1.0
INPCFD  825     101     10      PLOT3D   goland_NS.grid   $825
EXTFILE 825     goland_0.825_ns.sol
FLUTTER 825     SYM     825              0       0       0
FIXMDEN 825     825     0.002377  LBF/     FT                           +FIX701
+FIX701 300.0   320.0   340.0   360.0   380.0   400.0   420.0   440.0   +FIX702
+FIX702 460.0   480.0   500.0   520.0   540.0   560.0   580.0   600.0   +FIX703
+FIX703 620.0   640.0   660.0   680.0   700.0   720.0   740.0   760.0   +FIX704
+FIX704 780.0   800.0   820.0   840.0   860.0   880.0   900.0   920.0   +FIX705
+FIX705 940.0   960.0   980.0   1000.0  1020.0  1040.0  1060.0  1080.0  +FIX706
+FIX706 1100.0  1120.0  1140.0  1160.0  1180.0  1200.0  1220.0  1240.0  +FIX707
+FIX707 1260.0  1280.0  1300.0  1320.0  1340.0  1360.0  1380.0  1400.0  +FIX708
+FIX708 1420.0  1440.0  1460.0  1480.0  1500.0
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
$MKAEROZ 85      0.85    -3       85      SAVE    CBTN0850r2.AIC     0      +MK1
MKAEROZ 85      0.85    -3       85     ACQUIRE CBTN0850r2.AIC     0      +MK1
+MK1    0.025   0.075    0.15    0.3      0.5    0.75    1.0      1.2     +
+        1.6     2.0
TRIMFLT 85      85       1.0
INPCFD  85      101     10      PLOT3D  goland_NS.grid      $85
```

```
EXTFILE 85      goland_0.85_ns.sol
FLUTTER 85      SYM     85              0       0       0
FIXMDEN 85      85      0.002377  LBF/     FT                           +FIX701
+FIX701 300.0   320.0   340.0   360.0   380.0   400.0   420.0   440.0   +FIX702
+FIX702 460.0   480.0   500.0   520.0   540.0   560.0   580.0   600.0   +FIX703
+FIX703 620.0   640.0   660.0   680.0   700.0   720.0   740.0   760.0   +FIX704
+FIX704 780.0   800.0   820.0   840.0   860.0   880.0   900.0   920.0   +FIX705
+FIX705 940.0   960.0   980.0   1000.0  1020.0  1040.0  1060.0  1080.0  +FIX706
+FIX706 1100.0  1120.0  1140.0  1160.0  1180.0  1200.0  1220.0  1240.0  +FIX707
+FIX707 1260.0  1280.0  1300.0  1320.0  1340.0  1360.0  1380.0  1400.0  +FIX708
+FIX708 1420.0  1440.0  1460.0  1480.0  1500.0
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
$MKAEROZ 88      0.88    -3       88      SAVE    CBTN0880r2.AIC     0      +MK1
MKAEROZ 88      0.88    -3       88     ACQUIRE CBTN0880r2.AIC     0      +MK1
+MK1    0.025   0.075    0.15    0.3      0.5    0.75    1.0      1.2     +
+        1.6     2.0
TRIMFLT 88      88       1.0
INPCFD  88      101     10      PLOT3D   goland_NS.grid     $88
EXTFILE 88      goland_0.88_ns.sol
FLUTTER 88      SYM     88              0       0       0
FIXMDEN 88      88      0.002377  LBF/     FT                           +FIX701
+FIX701 300.0   320.0   340.0   360.0   380.0   400.0   420.0   440.0   +FIX702
+FIX702 460.0   480.0   500.0   520.0   540.0   560.0   580.0   600.0   +FIX703
+FIX703 620.0   640.0   660.0   680.0   700.0   720.0   740.0   760.0   +FIX704
+FIX704 780.0   800.0   820.0   840.0   860.0   880.0   900.0   920.0   +FIX705
+FIX705 940.0   960.0   980.0   1000.0  1020.0  1040.0  1060.0  1080.0  +FIX706
+FIX706 1100.0  1120.0  1140.0  1160.0  1180.0  1200.0  1220.0  1240.0  +FIX707
+FIX707 1260.0  1280.0  1300.0  1320.0  1340.0  1360.0  1380.0  1400.0  +FIX708
+FIX708 1420.0  1440.0  1460.0  1480.0  1500.0
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
$MKAEROZ 90      0.90    -3       90      SAVE    CBTN0900r2.AIC     0      +MK1
MKAEROZ 90      0.90    -3       90     ACQUIRE CBTN0900r2.AIC     0      +MK1
+MK1    0.025   0.075    0.15    0.3      0.5    0.75    1.0      1.2     +
+        1.6     2.0
TRIMFLT 90      90       1.0
INPCFD  90      101     10      PLOT3D  goland_NS.grid     $90
EXTFILE 90      goland_0.9_ns.sol
FLUTTER 90      SYM     90              0       0       0
FIXMDEN 90      90      0.002377   LBF/    FT                           +FIX701
+FIX701 300.0   320.0   340.0   360.0   380.0   400.0   420.0   440.0   +FIX702
+FIX702 460.0   480.0   500.0   520.0   540.0   560.0   580.0   600.0   +FIX703
+FIX703 620.0   640.0   660.0   680.0   700.0   720.0   740.0   760.0   +FIX704
+FIX704 780.0   800.0   820.0   840.0   860.0   880.0   900.0   920.0   +FIX705
+FIX705 940.0   960.0   980.0   1000.0  1020.0  1040.0  1060.0  1080.0  +FIX706
+FIX706 1100.0  1120.0  1140.0  1160.0  1180.0  1200.0  1220.0  1240.0  +FIX707
+FIX707 1260.0  1280.0  1300.0  1320.0  1340.0  1360.0  1380.0  1400.0  +FIX708
+FIX708 1420.0  1440.0  1460.0  1480.0  1500.0
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
$MKAEROZ 91      0.91    -3       91      SAVE    CBTN0910r2.AIC     0      +MK1
MKAEROZ 91      0.91    -3       91     ACQUIRE CBTN0910r2.AIC     0      +MK1
+MK1    0.025   0.075    0.15    0.3      0.5    0.75    1.0      1.2     +
+        1.6     2.0
TRIMFLT 91      91       1.0
INPCFD  91      101     10      PLOT3D  goland_NS.grid     $91
EXTFILE 91      goland_0.91_ns.sol
FLUTTER 91      SYM     91              0       0       0
FIXMDEN 91      91      0.002377   LBF/    FT                           +FIX701
+FIX701 300.0   320.0   340.0   360.0   380.0   400.0   420.0   440.0   +FIX702
+FIX702 460.0   480.0   500.0   520.0   540.0   560.0   580.0   600.0   +FIX703
+FIX703 620.0   640.0   660.0   680.0   700.0   720.0   740.0   760.0   +FIX704
+FIX704 780.0   800.0   820.0   840.0   860.0   880.0   900.0   920.0   +FIX705
+FIX705 940.0   960.0   980.0   1000.0  1020.0  1040.0  1060.0  1080.0  +FIX706
+FIX706 1100.0  1120.0  1140.0  1160.0  1180.0  1200.0  1220.0  1240.0  +FIX707
+FIX707 1260.0  1280.0  1300.0  1320.0  1340.0  1360.0  1380.0  1400.0  +FIX708
+FIX708 1420.0  1440.0  1460.0  1480.0  1500.0
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
$MKAEROZ 92      0.92    -3       92      SAVE    CBTN0920r2.AIC     0      +MK1
MKAEROZ  92      0.92    -3       92    ACQUIRE CBTN0920r2.AIC      0      +MK1
+MK1    0.025   0.075    0.15    0.3      0.5    0.75    1.0      1.2     +
+        1.6     2.0
TRIMFLT 92      92       1.0
INPCFD  92      101     10      PLOT3D   goland_NS.grid     $92
EXTFILE 92      goland_0.92_ns.sol
```

```
FLUTTER 92      SYM     92              0       0       0
FIXMDEN 92      92      0.002377  LBF/      FT                          +FIX701
+FIX701 300.0   320.0   340.0   360.0   380.0   400.0   420.0   440.0   +FIX702
+FIX702 460.0   480.0   500.0   520.0   540.0   560.0   580.0   600.0   +FIX703
+FIX703 620.0   640.0   660.0   680.0   700.0   720.0   740.0   760.0   +FIX704
+FIX704 780.0   800.0   820.0   840.0   860.0   880.0   900.0   920.0   +FIX705
+FIX705 940.0   960.0   980.0   1000.0  1020.0  1040.0  1060.0  1080.0  +FIX706
+FIX706 1100.0  1120.0  1140.0  1160.0  1180.0  1200.0  1220.0  1240.0  +FIX707
+FIX707 1260.0  1280.0  1300.0  1320.0  1340.0  1360.0  1380.0  1400.0  +FIX708
+FIX708 1420.0  1440.0  1460.0  1480.0  1500.0
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
$MKAEROZ 93      0.93    -3       93      SAVE    CBTN0930r2.AIC     0      +MK1
MKAEROZ 93      0.93    -3       93     ACQUIRE CBTN0930r2.AIC     0      +MK1
+MK1    0.025   0.075    0.15    0.3      0.5    0.75    1.0      1.2     +
+        1.6     2.0
TRIMFLT 93      93       1.0
INPCFD  93      101     10      PLOT3D   goland_NS.grid     $93
EXTFILE 93      goland_0.93_ns.sol
FLUTTER 93      SYM     93              0       0       0
FIXMDEN 93      93      0.002377  LBF/     FT                           +FIX701
+FIX701 300.0   320.0   340.0   360.0   380.0   400.0   420.0   440.0   +FIX702
+FIX702 460.0   480.0   500.0   520.0   540.0   560.0   580.0   600.0   +FIX703
+FIX703 620.0   640.0   660.0   680.0   700.0   720.0   740.0   760.0   +FIX704
+FIX704 780.0   800.0   820.0   840.0   860.0   880.0   900.0   920.0   +FIX705
+FIX705 940.0   960.0   980.0   1000.0  1020.0  1040.0  1060.0  1080.0  +FIX706
+FIX706 1100.0  1120.0  1140.0  1160.0  1180.0  1200.0  1220.0  1240.0  +FIX707
+FIX707 1260.0  1280.0  1300.0  1320.0  1340.0  1360.0  1380.0  1400.0  +FIX708
+FIX708 1420.0  1440.0  1460.0  1480.0  1500.0
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
$MKAEROZ 95      0.95    -3       95      SAVE    CBTN0950r2.AIC     0      +MK1
MKAEROZ 95      0.95    -3       95     ACQUIRE CBTN0950r2.AIC     0      +MK1
+MK1    0.025   0.075    0.15    0.3      0.5    0.75    1.0      1.2     +
+        1.6     2.0
TRIMFLT 95      95       1.0
INPCFD  95      101     10      PLOT3D  goland_NS.grid      $95
EXTFILE 95      goland_0.95_ns.sol
FLUTTER 95      SYM     95              0       0       0
FIXMDEN 95      95      0.002377  LBF/     FT                           +FIX701
+FIX701 300.0   320.0   340.0   360.0   380.0   400.0   420.0   440.0   +FIX702
+FIX702 460.0   480.0   500.0   520.0   540.0   560.0   580.0   600.0   +FIX703
+FIX703 620.0   640.0   660.0   680.0   700.0   720.0   740.0   760.0   +FIX704
+FIX704 780.0   800.0   820.0   840.0   860.0   880.0   900.0   920.0   +FIX705
+FIX705 940.0   960.0   980.0   1000.0  1020.0  1040.0  1060.0  1080.0  +FIX706
+FIX706 1100.0  1120.0  1140.0  1160.0  1180.0  1200.0  1220.0  1240.0  +FIX707
+FIX707 1260.0  1280.0  1300.0  1320.0  1340.0  1360.0  1380.0  1400.0  +FIX708
+FIX708 1420.0  1440.0  1460.0  1480.0  1500.0
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
OMITCFD 10              TECPLOT SURFACE.PLT     SURFACE.SOL
         1       1       81      1       65      1       10
         2       1       81      1       65      1       10
CORD2R  101             0.0     0.0     0.0     0.0     -1.     0.0
        1.0     0.0     0.0
```